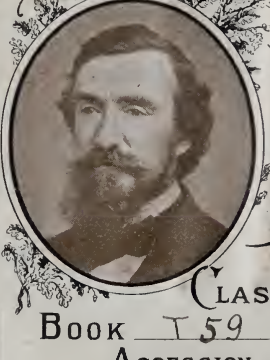
THE SCIENCE OF KNITTING

ERNEST TOMPKINS



THE SCIENCE OF KNITTING

AN ILLUSTRATED REFERENCE BOOK OF THE ELEMENTARY PRINCIPLES OF KNIT FABRICS AND MACHINE KNITTING, INCLUDING FUNDAMENTAL CONVENTIONS, DEFINITIONS, RULES, FORMULAS AND TABLES, FOR THE STUDENT, OPERATOR, MANUFACTURER AND ANALYST

WRITTEN BY

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FOR

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PREFACE

This book was begun as a proprietary publication, but as it soon developed beyond the scope of such a work it was turned into a scientific handbook for general use by the exclusion from the text of everything of an advertising nature, and by the addition of what seemed to be the most desirable technical information available. It is believed that the work will be of use in promoting the progress of the knitting industry.

WILDMAN MFG. CO.
Norristown, Pa.

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THE SCIENCE OF KNITTING

CONVENTIONS

The meaning of many of the technical terms used in this book is explained when they are brought into use, but the meaning of the most used terms and conventions is given here in order to make sure that they will be understood in case the explanation may not be with them when they are encountered.

Cut is used instead of needles per inch, both because it is quite generally so used and because it is much shorter than needles per inch. The only objection to its use is that it might be confused with the word cut used to designate the size of yarn, but since the yarn cut is restricted, is really unnecessary, and is not used with reference to the machine, there is not much chance for confusion. On the contrary, there are good reasons for abandoning it in favor of a familiar substitute, such as the cotton number, and leaving the word cut for use entirely instead of needles per inch.

Right Hand, applied to circular motion (or the result of it), means the direction of revolution of a right-hand screw when entering a solid body.

Clockwise means the direction of motion of the hands of a clock, which for circular motion is the same as right hand.

Left Hand is the reverse of right hand.

Anti-clockwise is the reverse of clockwise.

Forward means the direction of motion of whatever is the subject of discussion — such as yarn, machine, fabric, etc.

Backward means the reverse of forward.

Number means yarn number in the cotton count unless otherwise specified.

A Constant means a number which does not change, such as 3.1416, the number which expresses the ratio of the circumference of a circle to its diameter.

A Variable means a number which does change. The age of anything is a variable, since it is constantly changing.

Gauge, applied to the needle spacing or to the fineness of cloth, means needles per inch and one-half, which is substantially the original meaning of the word as applied to knitting.

Gauge, applied to needles, means the thickness of latch needles. There is no rule for determining the gauge from this dimension, so tables have to be consulted for such information. Other dimensions of the needle, such as size of hook, length of latch, etc., correspond to an extent to the gauge, but have no fixed relation to it. For instance, a 48-gauge needle has a certain thickness and a fine hook, but the hook may be more or less fine.

Diametral Revolutions means the product of the diameter in inches and the revolutions per minute of a revolving circle, such as a knitting machine, pulley or similar object. A 20-inch cylinder making 35 revolutions per minute is running at $20 \times 35 = 700$ diametral revolutions.

Abbreviations

Abbreviation	Meaning
+	Increased by
−	Decreased by
×	Multiplied by
÷	Divided by
=	Equals
dia.	Diameter
r.p.m.	Revolutions per minute
dia. r.p.m.	Diametral revolutions
√	Square root of
i.e.	That is
e.g.	For instance
q.v.	Which see.

SUGGESTIONS FOR A COURSE OF READING

If all knowledge of machine knitting were taken out of the world, and a perfect knitting machine, say a rib body machine for example, were set down in a knitting center, such as Leicester, England, or Utica, New York, with no more information than the assurance that it would knit cloth, it is safe to say that after repeated efforts to hook on the fabric and get it started, the machine would be so damaged and the operators so discouraged, that it would be pronounced an impossibility to make cloth on such a machine.

Somewhat similarly, if a book announcing and demonstrating a system of knitting calculations is put into the hands of readers who do not even know that there is system in knitting, and most of whom are unfamiliar with mathematical demonstrations, such a book would not be very beneficial without an explanation of how to use it.

Other important callings, civil engineering and mechanical engineering for examples, have their handbooks; but before the appearance of such books, the readers were prepared to understand them by technical school and college instruction.

Moreover, if the author of these knitting calculations frequently finds it necessary to take paper and pencil and carefully work out something which he himself has written in order to re-understand it, how much more will assistance be useful to one who has never heard of a knitting system and has never been prepared to understand one if it should appear.

Although the above considerations show the advisability of helps in the use of this book, there are other reasons why sympathy for the knitter and his calling should prompt a familiar attempt to improve both, in spite of the prevailing unsympathetic custom of disseminating cold facts without aids to the understanding of them.

One reason is the value of machine knitting to the human race. The frame tender in an obscure little mill who longs for bigger and better things seldom realizes that he is doing as much knitting as fourteen thousand grandmothers with their hand needles, and just as the product of that hand knitting benefited his immediate family, so his work, thousands of times more, benefits members of his bigger human family so numerous and so far away that he can never know them.

Another reason is the opportunity to benefit the knitter as a class. Who is there with any experience in the industry who has not known of a knitter's leaving his home town for a better opening, and then drifting back with the remark, "Yes, the wages were better, but the machines ran the other way and the yarn count was different, and I couldn't catch onto it." What a commentary! A knitter at home and not abroad! Suppose the mechanic said, "I am a machinist in Saratoga County but not elsewhere." What kind of a machinist would he be? For what reason is a knitter's knowledge limited to one locality, when the machinist's, the carpenter's, the mason's is universal.

For no reason. It is unreasonable. For what cause, then? Because the fundamentals have not been offered to him.

Intimate acquaintance with the knitter and his surroundings shows the need of these appeals for improvement notwithstanding the fact that such appeals are unconventional and sure to be misunderstood by some who regard an offer of better educational facilities as an imputation of ignorance. The error of such a position should be evident from the fact that the enlightenment of the entire knitting world is ignorance compared to that of almost every other branch of human endeavor.

It is what we retain which benefits us, not what we hear. A man might hear good sermons every Sunday of his life and good advice every week day, but if he retain nothing of either, he will not benefit thereby. Technical knowledge is not retainable by the mere reading of it. The reader must take pencil and paper and put down in black and white the main truths if he is to be benefited by them. And while he is about it he might use a pen and indexed notebook and put those truths down where they will be readily available. Nystrom, in the preface to his handbook, put these words: "Every engineer should make his own pocket book, as he proceeds in study and practice, to suit his particular business." Nystrom's handbook has been superseded. Why? Largely because others made more complete handbooks from Nystrom's suggestion. And it is probable that this one sentence in Nystrom's book will be of more value to the world and live longer than all the rest of Nystrom's book put together, for the sentence will never become obsolete whereas the rest of the book will. Consequently, the knitter who does not begin the reading of this handbook by starting one of his own will miss not only the spirit and benefit of this book but he and the world will miss the benefit of his own book.

What connects knitters all over the world? Knit fabric. It may have been made by a Yankee, or a Frenchman, on a latch needle, or on a spring needle, on a round machine, or on a straight machine, — possibly an expert might tell some of the latter details, but every knitter recognizes the knit stitch itself, and every true knitter is attracted by it. Therefore, the way for broadening the knitter's horizon is through the fabric. But the fabric is made from yarn, so the beginning is there. This book does not treat of the composition of yarn, since such information may be found in numerous books and since one idea of this book is not to repeat except where improvement seems evident. Yarn composition is important and should be studied elsewhere, but yarn diameter is mechanically the most important and is treated here in a readily understandable way under

Yarn Diameter

The student should read this topic carefully and then apply the principles by determining the diameter of some yarn. If no hosiery yarn is at hand, a few pieces of soft cord, such as is used for tying bundles, will answer the purpose.

Elements of Knitting

The first part of this is plain sailing, but it is important since it defines the terms commonly used in knitting. The student should learn the application of the terms, such as needle wale, sinker wale, course, etc., and should form the habit of using them. Otherwise the descriptions which follow will not be readily understood.

The first mathematical portion of the elements is the derivation of the general rule

$$\text{Yarn number} = \frac{\text{Cut}^2}{\text{Constant}}.$$

This is one of the most important relations in knitting, so of course it is desirable that the student be able to derive it from the definitions of cut and number, since then he will not only understand it better, but will be able to conjure it up when he needs it. However, inability to derive the rule does not detract from its usefulness any more than does inability to derive the rule for the horse power of a steam engine. Consequently, the derivation may be skipped by those who find it laborious, but the result should be thoroughly memorized.

The latter part of the elements, that which contains the explanation of the underlying principles of knitting for (1) stitches constant, (2) yarn constant and (3) loops proportional to the diameter of the yarn, is very important. It is the theory of knitting put in language meant to be plain. It should be read with a pad and pencil at hand for working out the simple illustrations in order to fix the principles; and should not be left until it is mastered since practically all that follows is dependent on it.

Practical Variations from Knitting Rules

This is easy reading but highly important for several reasons. In the first place, mere book learning is even more deficient than mere practical learning. So the student of books is justly under the suspicion of impracticability until he has proven otherwise; and the best way in which he can prove otherwise is to admit freely his limitations. Therefore, the student should learn as early as possible how much allowance to make between theory and practice. He should put every principle to the severest test and should not depend on memory for the results of the tests but should put down on paper the discrepancies between the rules and the actual results, and should then derive the average maximum and minimum errors. These results should be kept with each formula, for no formula is complete without knowledge of its reliability. The formulas for regular fabrics are so new that only a little such knowledge is available for them, therefore the user must find the rest for himself.

Relation of Machine Gauge and Cut

This should be learned.

Yarn-gauge Rules and Charts for Latch-needle Rib and Spring-needle Loop-wheel Machines

These rules connect the fabric with the machine which makes it and, therefore, are highly important, but the allowable variation from them is also important, so the charts showing the variations should be studied until the information in the charts can be properly applied.

Formulas for Regular Rib Fabrics and Explanations: Formulas for Regular Flat Fabrics and Explanations

These are the means of practical application of the theory of knit fabrics — rather the principles of knit fabrics — so the student should study them by working out examples with the formulas which are designated the most important in the explanations. Of course the Tabulations for Regular Fabrics belong with the formulas and should have the attention which they deserve. The student should understand thoroughly that although the principles of the formulas are on a substantial basis the constants used are a matter of choice. For instance, in his locality fabric which has courses to wales as 12 to 10 may be considered to represent best average practice. In such case the ambitious student may test his ability by working out a set of formulas for those conditions.

The Relation of the Diameter of the Yarn to the Needle Spacing

This is somewhat mathematical, but if found difficult the mathematics may be skipped. However, the results should be understood and considered. As a general rule, the machine which works the heaviest yarn in proportion to the needle spacing is technically the best machine. This indicates that it is desirable to find means of using heavy yarn, especially on those machines which are now restricted to comparatively light yarn. Of course, the practical problem involves retaining good needle velocity and a reasonable number of feeds, but any discovery which will throw light on the subject is valuable.

Width of Fabric from Different Machines

This subject is much like the last. It may seem dry but it is useful.

Range of Fabric from the Same Gauge or Cut

This is an illustration of how much difference there may be in fabrics from the same number of needles per inch. Yet it has been customary to try to determine the cut from the fabric. It should be evident that the fabric rules given in this book provide a more rational and accurate method for determining the needles per inch.

Production of Circular Knitting Machines

This gives the general considerations of the production question and deserves to be read thoroughly.

Production — Methods of Calculating

The student should take his pencil and paper and work through each method as it is given, then he should work each one through with the book closed, and finally he should work each one through with an entirely new set of conditions. Even then he will be fortunate if he remembers the methods sufficiently for application on the spot, since these methods are as easy to forget as they are important. A boiler maker who could not calculate the capacity of his boilers, or an engine maker who could not calculate the capacity of his engines, would be regarded as an ignoramus; yet the knitter, as a rule, cannot calculate the capacity of his machines, although this is one of the simple problems in knitting. Therefore, the student of knitting should learn the subject, not only because he may require it, but because it helps to put his calling on the higher plane where it should be.

Relative Production of Different Types of Knitting Machines

This is a highly important question and one which tests the reader's knowledge of what he has already read. It frequently happens that a cotton yarn company desires to install machinery to convert the yarn into fabric. What machines should be installed to convert the most pounds or to produce the most yards? The knitter should be able to answer questions like these. If he studies this topic, he will be able to do so.

Weight per Square Yard Formula — Derivation

This formula is to knitting what the first law of gravitation is to the heavenly bodies. Astronomers used to be puzzled by the difference in motion between a planet and a comet, and by lesser differences in the motions of any two planets. But the first law of gravitation, namely, that bodies attract each other directly as their masses and inversely as the square of their distance, solved the whole problem; so that a law expressible in sixteen words bound the immeasurable universe together. Similarly the weight per yard formula binds all knit fabric together, for it states the conditions which control every piece of knit fabric. This derivation is simple arithmetic and it is so important that every knitter should learn it and be able to derive it at any time.

Determining the Weight per Square Yard by Weighing

Although this topic is intended for the manufacturer or analyst who will do enough weighing to warrant the cost of a die for cutting the fabric, it is useful to the student as well. If a die is not readily procurable, the student may cut out rectangular pieces of cloth, using for a pattern a piece of cardboard, say four inches square.

Two-thread Knitting

Twist in Flat Knit Fabric Made with Self-feeding Needles

Twist in Rib Fabric

Summary Regarding Twist of Knit Fabrics

These are easy reading, but they should not be slighted because they are easy. The student will find in them many principles which have much broader application than the titles indicate, and he should endeavor to understand those principles in order to extend their application himself. For instance, the subject of twist in knit fabrics and knitting yarn is as broad as its investigation has been narrow, so it offers a good field for study.

Yarn Counts — General

The knitter works with yarn, so he is not thoroughly equipped for his occupation until he understands the methods of numbering yarn. It is a sad reflection on our civilization that so much time has to be wasted in learning many different counts when a few would answer the purpose; but if the time consumed spurs the student to use his influence toward the adoption of two or three universal yarn counts, it will not be entirely lost.

Yarn-count Definitions

These should be memorized. Undoubtedly, some of the definitions will be forgotten in time, but if the student memorizes them when the subject is in hand, he is likely to retain a sufficiently clear idea of them to be of service in time of need.

Counts Used for Different Kinds of Yarns

This old subject is treated briefly for the American knitter, since the usual treatise is either too voluminous or does not include the local counts. The pitfalls of yarn numbering should be carefully learned, for it is frequently costly to specify the wrong number of yarn. Moreover, it is advisable to know something about the local yarn numbering when one goes to a new locality, since the knowledge dispels the to-be-expected suspicion of provincialism.

Single Equivalent of Two or More Yarns — Formula

The equation for two yarns should be thoroughly learned, even if the demonstration is too difficult. Moreover, the equation should be practiced until proficiency in its use is attained. When the knitter is asked what the equivalent of a ten and six yarn is and has to admit that he does not know and cannot find out without a table, his admission is a sad commentary on his knowledge.

Explanation of Yarn-transformation Table — Yarn-transformation Table

These should be mastered. Some may say that they have a parallel column transformation table with which they are familiar. That is all right for whoever does not use yarn every day, but the knitter should be able to transform between the counts which he uses without the aid of a table. He may be looking for a position some day, and the prospective employer may ask him a simple transformation question, just as a seaman is asked to box the compass as a slight evidence of his knowledge. If he says that he does not know but must go home and look in a book to find out, he is likely to be advised to go home and stay there. Very many of the usual yarn transformations are solvable almost or entirely mentally, and it gives standing to a knitter to be able to answer such questions on the spot. It is not to be expected that all of the constants will be learned, but if a knitter uses cotton, worsted and millspun yarn, he should be able without looking at a book or a memorandum to make any transformation between the cotton count, worsted count, and whatever local count is used.

Figure Designing with Pattern Wheels

Although this is generally regarded as belonging more to loopwheel knitting than to general knitting, still the principles are broad even if the application is somewhat restricted. Moreover, the mental training obtained by mastering such problems is highly beneficial. The man who is content to have all of his information brought to him ready for use will become dependent just like the man who requires all of his food brought to him. But those who exercise either their minds or their muscles — and preferably both — for what they get are independent, as all rational beings should be.

Minimum Weight per Square Yard

This is an illustration of the purely theoretical. Fabric of the kind discussed is never seen. Naturally, some think that time spent in discussing it is lost. But such people would be surprised if they would learn how much our present knowledge of common affairs has been increased by discussing the infinitely great and the infinitely small. Yet neither will ever be reached here. However, from those unattainable boundaries it is possible to work back and derive much practical information. It is so with the minimum weight per square yard; it sets a limit which assists in determining the attainable weights. But better still it shows how reasoning can be applied to knitting for its advancement as well as to anything else. Moreover, the knitter should not leave such reasoning for the so-called theorists. The knitter has the same kind of a brain as the theorist and frequently a better opportunity to use it, and he should exercise the opportunity.

Vertical Patterns

This topic is something like Figure Designing in that it is certainly beneficial as a study, even if the opportunity does not occur for its application.

Economics of Knitting

Economical knitting is what every knitter is striving for, since, if he does not get pretty near to it, competition will drive him out of business. Therefore, it ought to be of interest and value to know definitely just what roads lead to economy instead of groping around in the dark for them. Economics of Knitting points out those roads. The subject may seem dry. So are the economics of almost every industry. But by such dry subjects is progress made.

Theory of Knit Fabrics

This is not intended for practical knitters since they have already learned it from the Elements of Knitting. It is for those who want to get quickly at the reason for the knitting system which this book proclaims. It is a line of departure for those who feel prompted to express agreement or disagreement. The author hopes that all such will carry out their promptings with as much fidelity as has been exercised in developing the system itself, since only by such criticism can the truth be reached. The object of this book is to show the truth, and those who support its truths or correct its errors will be furthering that object.

The Remainder of the Book

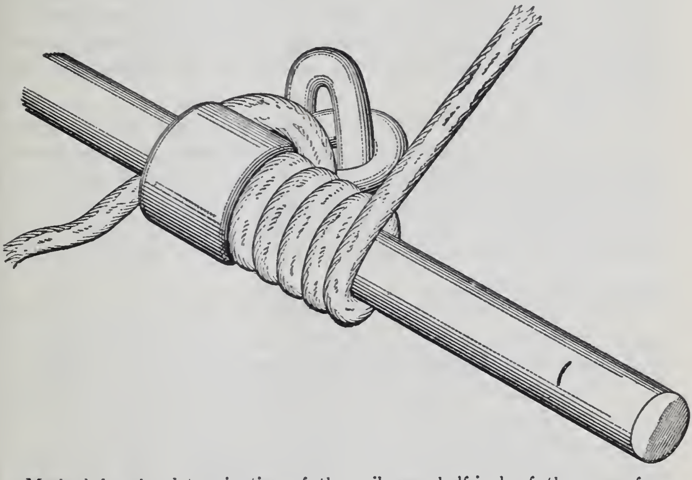
This needs no introduction other than the index and table of contents. The knitter should remember, however, that although the tables are for him as well as for those who are not knitters, still he should not be dependent on the tables, since if he has followed these suggestions he already knows formulas enough to enable him to derive hundreds of tables. These tables are merely some of those rules worked out for cases which might arise, in order to save the time of working them out when the cases do arise. So the rule is the main thing. Moreover, the knitter can carry the rule in his head, but not the table. Therefore, he should keep the rules in his head and be able to apply them whenever it is necessary.

YARN DIAMETER

It is the custom to use the yarn number in knitting calculations, which is right as far as it goes, since the number expresses the inverted weight per unit length of the yarn and is, therefore, useful, very much as the weight per foot of shafting is useful. But if a machinist were required to construct something with shafting and had to work by the weight per foot instead of the diameter, he would be sadly inconvenienced. Yet this is the condition under which the knitter has worked — a condition which is responsible for much confusion and waste. The knitting machine is insensible to the weight of yarn, but it is very sensitive to undersized or over-sized yarn. Of course, the weight has a relation to the diameter, but this relation is so affected by the composition, twist, and hygroscopicity of the yarn that it is not reliable for determining the diameter except when these and other disturbing conditions are alike.

Although the number of the yarn is useful and therefore desirable for knitting purposes, the diameter or an equivalent is much more desirable, since the width of the fabric, the cut of the machine, the length of the stitch, and other important features are dependent on it.

It is generally considered that the actual or sensible diameter — the diameter which the machine experiences — is almost impossible to determine. In weaving, calculations are made with diameters derived from the specific weight of the material, cotton, wool, etc., as the case may be, but these diameters are less than the sensible diameter. Moreover knitting — especially in America — has not yet reached the calculating stage, so whatever diameters are used must not only be such as the machine experiences but must be convenient of access and simple to handle.



Method for the determination of the coils per half-inch of the yarn, from which the diameter of the yarn, the diameters per inch, and the yarn number may be calculated.

A means of meeting all these requirements is illustrated herewith. Almost every one has a watch-chain bar. Make a very slight nick in the bar half an inch from the nearest side of the band. Wind the yarn in question around the bar out to the mark, say five slightly separated coils at a time, pressing each five coils toward the band, so that they come firmly together, but are not compressed too tightly. Then *one-half divided by the number of coils gives the diameter of the yarn.* But it is not necessary to make the division since the number of coils is as reliable to work with as the diameter and is much more convenient. By this means, from what follows and with only a piece of yarn, say eight inches in length, the knitter may determine the cut to use, the stitches per foot, the number of the yarn and other useful information. Moreover, skill in coiling the yarn may be acquired with less practice than is required for the use of a reel and balance. The novice should not be discouraged if the yarn number obtained by this method does not exactly agree with the number obtained by reeling, for it has already been shown that the diameter does not always correspond with the number, so it must follow that the number does not always correspond with the diameter. Consequently failure to get the correct number by counting the coils is not necessarily proof that either the method or the application of it is faulty.

Of course there are with this method, as with every other, sources of error, opportunities for carelessness, etc. such as chancing on an exceptionally light or heavy piece of the yarn, or pressing the coils differently, or using a rough or sticky bar; but with ordinary caution this method affords the knitter an exceedingly simple guide which is far ahead of what has formerly been available.

In the following discussion the yarn diameter and the coils are obtained with a bar. The coils per one-half inch are generally used since the coils per inch are too many to count readily and no advantage is gained by using them, except for more elaborate calculations than the knitter is likely to make. Obviously the number of coils per half inch is half the number of coils per inch. So in order to prevent confusion, the coils per half inch are so stated, or as " one-half coils per inch," whereas " coils " means coils per inch.

ELEMENTS OF KNITTING

Definition of Knitting. — Knitting is making fabric on more than one needle by interlooping a thread or several parallel threads.

The Loop is the Element. — Since the fabric is made up of a succession of loops, the element of the fabric is the loop.

Course. — Successive loops in any one thread form a course, except in warp knitting where the loops formed at one time form a course.

Length of Course. — In circular knitting a course follows a continuous helical path in the tube of fabric from beginning to end, so its length is inconveniently great; consequently the length is taken as one complete circuit of the fabric, and successive circuits are regarded as separate courses.

First Course. — The first course may be formed in any one of many ways, such as wrapping the yarn once around each needle in succession, or may be in a fabric previously knit.

Formation of Loop. — In the latter case a needle is inserted through each one of the original loops and yarn is thereby drawn through the original loops to form the next course which is held on the needles until the operation is repeated, and so on.

Needle Loop. — The yarn lies in the plane of the fabric in what is called a snake curve, and the loops which are drawn through the previously formed loops are called the needle loops because they rest on the needle.

Sinker Loop. — But since the yarn is continuous there must be corresponding connecting loops of opposite curvature; these are called sinker loops, because in the original knitting machine during the feeding of the yarn they rested against thin plates called sinkers.

Wale. — A row of adjoining loops in different courses is called a wale or rib.

Stitch. — A stitch is really the combination of loops from adjoining threads forming a fixed part of the fabric, and the duplication of which forms the whole fabric.

But a stitch is frequently considered to be the length of yarn from any point to an adjoining corresponding point, e.g. from the middle of a sinker loop to the middle of the next sinker loop.

Top and Bottom of Loop and Fabric. — The needle loop is considered to be the top of the stitch and the sinker loop the bottom.

Correspondingly the bottom of the fabric is that which is knit first and the top is that which is knit last.

Length and Width of Fabric. — The extent of the fabric along the courses is limited by the number of needles, but along the wales it is unlimited except by the supply of yarn, so the length of the fabric is taken as the length of a wale, and the width, as the length of a course, except in tubular fabrics in which half the length of a single course is taken — that is, the flattened width of the tube.

Suppositions. — For the discussion of the elementary principles of knitting, the yarn is considered round and flexible to bending but not to compression. The machine is considered to be ideal, i.e. perfect in its operation and without limitations as

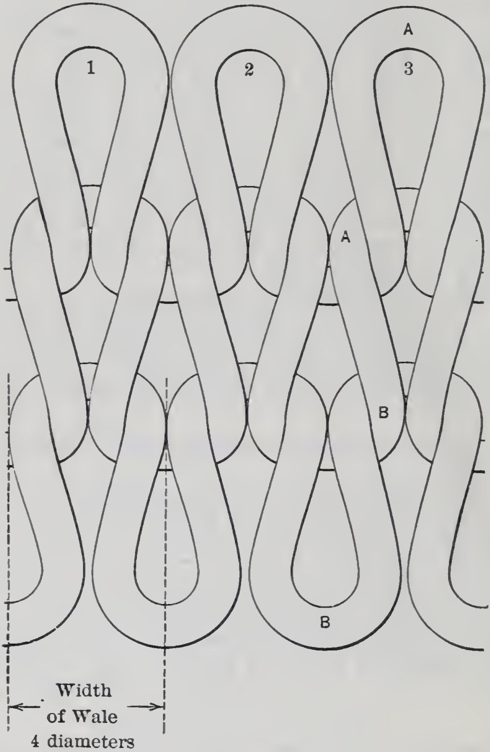


Illustration 1.

Face of plain flat fabric. A, A, needle loops, B, B, sinker loops.

to length of stitch, size of needle, etc. The practical qualifications are given subsequently.

Illustrations of Knit Stitch. — Illustration 1 shows a face view and Illustration 2 shows a back view of three wales, marked 1, 2, 3, of plain flat (not ribbed) knitting.

Width of Wale and of Fabric. — A wale at its widest part is made up of a loop bent over two threads side by side, and since these are all the same thread, the diameters are all the same, so *the width of the wale is four diameters.*

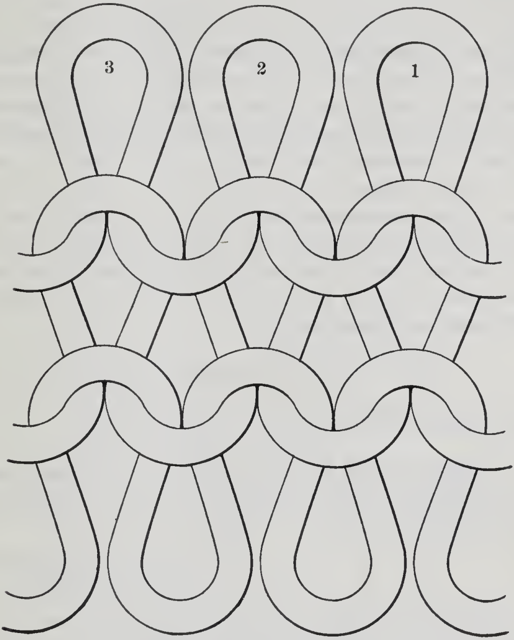


Illustration 2.
Back of plain flat fabric.

But the wales touch at their widest portion so

The entire width of the fabric = width of wale × number of wales
= 4 dia. of yarn × number of wales
= 4 dia. of yarn × number of needles.

The half width or flattened width of the tube = 2 dia. of yarn × number of needles
= 2 dia. of yarn × dia. of machine × 3.14 × cut
= 6.28 dia. of yarn × dia. of machine × cut.

From this it follows that the width of the fabric is dependent not only on the diameter of the machine but on the cut and on the diameter of the yarn. This is actually demonstrated in regard to the cut by some small mills which have only a few diameters of machines, but make a wide range of garment sizes by using cylinders and dials of different cuts in the same machine. It is evident also that if yarn of smaller diameter is used, the width of the fabric will be proportionally less. This may be counteracted by increasing the diameter of the machine with the same cut, as is well known, or by using a cylinder and a dial of correspondingly finer cut.

$$\text{Since dia. of yarn} = \frac{\frac{1}{2}}{\text{Coils per } \frac{1}{2} \text{ inch}},$$

$$\text{Width of flattened tube of fabric} = \frac{\text{Needles}}{\text{Coils per } \frac{1}{2} \text{ inch}}$$

i.e. *The flattened width of the tube of plain fabric from a circular machine equals the number of needles divided by the number of coils of yarn per half inch.*

$$= \frac{3.14 \times \text{dia. of machine} \times \text{cut}}{\text{Coils per } \frac{1}{2} \text{ inch}}.$$

i.e. *The flattened width of the tube of plain fabric from a circular machine equals 3.14 multiplied by the diameter of the needle line multiplied by the cut and divided by the coils of yarn per half inch.*

Width of Course. — A visible course is narrower than the height of a stitch, since the loops overlap by approximately a diameter both at the top and at the bottom.

Moreover, the width of the course is determined by the length of yarn in the stitch as well as by the diameter, instead of by the diameter alone as is the case with the wale.

Courses and Wales per Inch. — Courses are generally compared by the number per inch, as are also the wales, but since the width of the fabric is proportional to the number of wales, the width is generally used instead of the wales per inch.

Stitches per Foot. — The length of yarn in the stitch is expressed by the number of stitches per foot of yarn, since this is a convenient unit. It should be remembered, however, that the length of the yarn in the stitch increases as the stitches per foot decrease — just as the wales per inch decrease when the width of the wale increases. These are what are called inverse relations — that is, one goes up when the other goes down. There are many such in knitting, and they must be kept in mind in order to comprehend the subject.

Face and Back. — Each of the loops of the plain fabric is drawn through another one toward what is considered the face

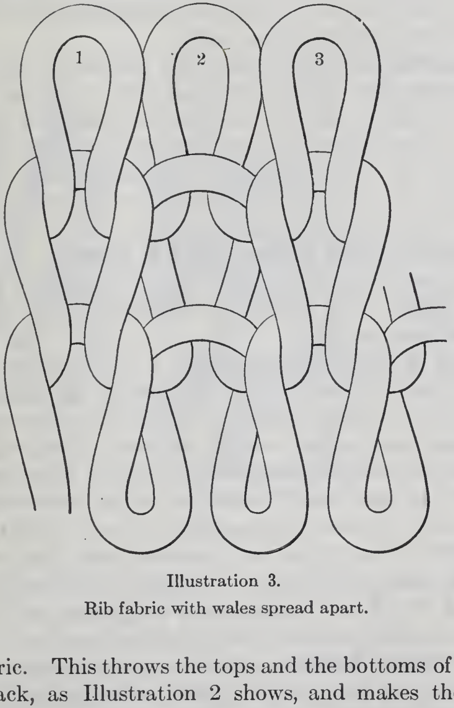


Illustration 3.
Rib fabric with wales spread apart.

the fabric. This throws the tops and the bottoms of the loops the back, as Illustration 2 shows, and makes the appearance of the back different from that of the front, or face.

Rib Fabric. — Now consider the loops of every other wale to drawn through to the back instead of the front. Then Illustration 1 will appear like Illustration 3, except that wales 1 and 3, coming together, will leave wale 2 entirely on the back. The face of the cloth will appear just the same as before, and the back will appear just like the face, since the tops and bottoms of the loops will be hidden between the front and back wales.

Curling of Edges of Flat Fabric. — The objectionable curling of the edges of flat fabric is due to the accumulated straightening out of the yarn in the stitches, which tendency is all in one direction in any one place — toward the face at the ends and toward the back at the sides — since the loops are all formed alike. But in rib fabric, where every alternate stitch in a course is drawn in the reverse direction, the tendency to straighten does not accumulate but counterbalances, therefore the fabric does not curl at the edges.

Raveling Flat and Rib Fabric. — It will also be noticed that the flat fabric may be raveled from either end, so that it is difficult to tell the top from the bottom when it is not on the machine; whereas the rib fabric cannot be raveled at the end which came off the needles first — the lower end, Illustration 3 — because the end thread is wound around the next thread instead of being merely looped through it.

Comparative Width of Flat and Rib Fabric. — If the same number of needles is used, the rib fabric will be half as wide as the plain fabric, since half of the wales lie on the back. The courses will not be changed.

Elasticity of Flat and Rib Fabric. — It is evident from the preceding that rib knitting is substantially flat knitting with every other wale facing inward, and since the wales on the inside overlap those on the outside, *rib fabric is only half as wide as flat fabric made of the same yarn and with the same total number of needles.* In other words, rib fabric of the same width as flat fabric made of the same yarn has twice as many wales to stretch; consequently it has twice the elasticity from this fact alone. Moreover, when rib fabric is stretched, the front and back wales tend to get into line between each other, and so supply still more elasticity than has just been mentioned.

Double Sets of Needles. — In rib machinery the needles are divided into two sets; one for knitting the face and the other for knitting the back. These sets are distinguished by various names, but in circular latch-needle machinery the needles which knit the back are generally called dial needles, and those which knit the face are generally called cylinder needles. Since for plain rib fabric the same number of needles is used in each set, and since the cylinder needles generally knit the face of the cloth, the number of cylinder needles is used to designate the fineness of the fabric or the machine, and it is understood that the same number of dial needles is also used.

Stitches per Foot. — The above designation makes the length of a rib stitch include both a cylinder and a dial stitch, so that thirty-two stitches per foot of yarn means thirty-two cylinder stitches and thirty-two dial stitches, or what would be sixty-four stitches in plain flat fabric.

Illustration 4 shows a front view and an edge view of a tight rib stitch. The following is evident:

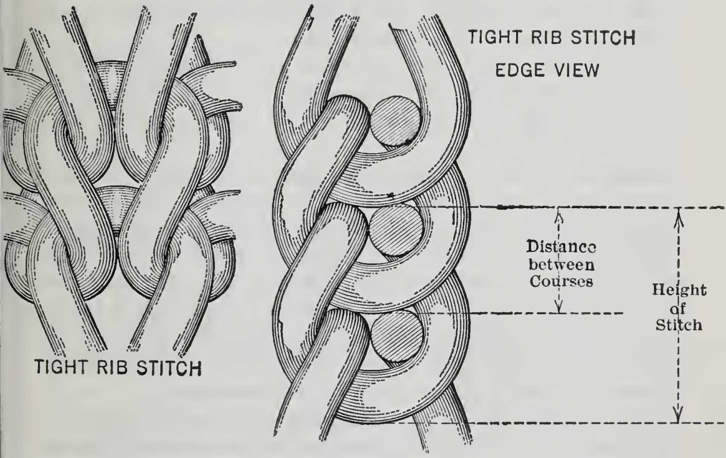


Illustration 4.

Dimensions of Rib Stitch. — The width of the wale is four diameters, as has already been shown.

The thickness of the fabric is four diameters.

The height of the stitch is four diameters.

Stitches of Different Fabrics of the Same Characteristics are Proportional to the Diameter of the Yarn. — From the above it follows that the stitch is proportional to the diameter of the yarn, for if the diameter is doubled, every dimension of the stitch will be doubled, including the length of yarn in the stitch. In other words, *corresponding stitches are proportional to the diameter of the yarn.* The student should fix this thoroughly in his mind. A good way of so doing is to look at Illustration 4 through a reading glass held at different distances from the illustration. The size of the stitches will increase and decrease just as the diameter of the yarn does. Note that these different sized stitches seen through the glass are corresponding stitches — that is, the tightest for any given diameter of yarn. But the rule holds for any other corresponding stitches regardless of their length.

Fabrics of Different Characteristics have Disproportionate Stitches. — However, *for stitches which do not correspond, whereas the width and thickness must be proportional to the diameter of the yarn, the length of yarn in the stitch and consequently the height of the stitch are not proportional.*

If the stitches are not proportional, the fabrics are different. So the converse of the rule is true; that is, *in dissimilar fabrics the lengths of yarn in the stitches are not proportional to the diameters of the yarn.*

Relation of Yarn Diameter and Needle Spacing. — Suitable yarn is that which the machine most economically converts into the most desirable fabric. *The diameter of the yarn is proportional to the spacing of the needles.* A convenient proof of this is found in the fact that ordinarily the width of the fabric is proportional to the width or diameter of the machine. From this it follows that when the number of needles is increased (i.e. when the cut is made finer) the width of the wales must be proportionally decreased or else the fabric would be made wider.

Proofs of Relation of Yarn Diameter and Needle Spacing. — The diameter of the yarn is proportional to the width of the wale. Consequently, the diameter of the yarn is reduced in proportion to the spacing of the needles. This important relation of the diameter of the yarn to the needle spacing was made public by Gustav Willkomm, who observed it from a comparison of the needle spacing of hosiery frames and the yarn diameter; it was much later independently observed from a comparison of the gauge and corresponding yarn diameter of American and Canadian practice; and was soon after announced to be a general relation dictated by the characteristics of knit fabrics and conformed to by the machine manufacturers or users.

Relation of Yarn Diameter and Needle Spacing is Elastic. — Since all practical machines will knit successfully yarn differing in diameter within a wide range, there is naturally room for a difference of opinion regarding the proportion of yarn diameter to needle spacing, but *whatever proportion is selected for any one kind and cut of machine is equally suitable on all the other cuts.* The proportions used here are from quite extensive practice and are useful, but should not be taken as final. Indeed, from the principles previously explained and from the application of them, explained hereafter, the knitter may derive his own proportions.

Formulas of Yarn and Cut Relation. — For instance, we have the rule that for corresponding fabrics

$$\frac{\text{Dia. yarn}}{\text{Needle spacing}} = \text{a constant}, \quad . \quad . \quad . \quad . \quad (1)$$

and remembering that

$$\text{The cut} = \frac{1}{\text{Needle spacing}}, \quad . \quad . \quad . \quad (2)$$

we have

$$\text{Needle spacing} = \frac{1}{\text{Cut}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Substituting in (1) the value of needle spacing in (3) we have

$$\text{Dia. yarn} \times \text{Cut} = \text{a constant}. \quad . \quad . \quad . \quad . \quad (4)$$

That is, as the diameter of the yarn increases, the cut decreases and vice versa. To use this rule with the coils instead of the diameter, substitute $\frac{1}{\text{Coils}}$ for diameter of yarn which gives $\frac{\text{Cut}}{\text{Coils}} = \text{a constant}$. Similarly, $\frac{\text{Cut}}{\text{Coils per } \frac{1}{2} \text{ inch}} = \text{a constant}$.

Suppose the knitter is running satisfactorily 12 cut machines and the yarn shows 51 coils in half an inch. Then for his conditions

$$\text{Constant} = \frac{\text{Cut}}{\text{Coils per } \frac{1}{2} \text{ inch}} = \frac{12}{51} = \frac{1}{4.25}.$$

Consequently, his rule for such conditions is

$$\text{Cut} = \frac{1}{4.25} \times \text{coils per } \tfrac{1}{2} \text{ inch}.$$

If he runs heavier or lighter yarn, the constants for such conditions may be derived in the same manner. The rule is applicable to all knitting machinery, but the constant is different for different types of machine because differences in structure limit the size of the yarn to be used. Spring-needle machines with jack sinkers, such as the Cotton and the Fouquet types, can use heavy yarn and, consequently, a very wide range of yarn. Spring-needle fixed-blade loop-wheel machines are restricted to light yarn. Circular latch-needle machines have a narrower range than loop-wheel machines, and the use of two sets of needles generally restricts the range still more. Constants for several types of machines are given elsewhere.

Relation of Yarn Number and Diameter, and Machine Cut

The cotton number of yarn is the number of yards in one pound divided by 840. Or, it is the number of 840 yard hanks in a pound. Hank is the name given to a fixed length of yarn. The hank of actual yarn is generally coiled and twisted, since it is too long to handle otherwise. Those who are familiar with yarn numbering have no trouble in realizing that the yarn number is 1 ÷ the weight of a hank; since if each hank weighed half a pound, there would be two hanks to the pound, and the yarn would be number two, which is the same as dividing 1 by $\frac{1}{2}$, the weight of the hank. However, those who are not familiar with yarn numbering sometimes have difficulty in grasping the hank idea, and even those who are familiar with the subject sometimes become confused when they try to figure out the relation of the diameter to the number. The following analogy may make the matter clearer. Suppose that instead of soft fuzzy twisted material, yarn is hard and smooth and round like a lead pencil, but still continuous in length. Then suppose that the yarn number is the number of one-inch pieces in a pound, since it is easier to imagine a one-inch piece than an 840-yard piece. If one inch of a certain piece weighed one-tenth of a pound, then it would take ten pieces to weigh a pound, so that yarn would be number ten. The number ten could also be obtained by dividing 1 by the weight of one inch, the standard length. Consequently,

$$\text{No.} = \frac{1}{\text{Weight of}}$$ 

In other words, the number equals one divided by the weight of a piece one inch long. Therefore, the diameter is the only dimension which can be changed, since the length is fixed, namely 1 inch. But the weight is proportional to the square of the diameter. That is to say, if the diameter is doubled, the weight is made four times as much; but two multiplied by two equals four, so the proportional weight after doubling the diameter may be obtained by multiplying the diameter by itself, i.e. by squaring it. But when the *diameter increases*, the weight does the same, consequently, the *number decreases*. Therefore a thick piece of yarn has a smaller number than a thin piece. This brings the illustration to the desired point, which is that *the yarn numbers are inversely proportional to the squares of the yarn diameters*. Inversely means inverted, or upside down. Consequently, to get the relative numbers of yarn square their diameters and turn the squares upside down, that is, for each yarn divide one by the diameter squared. These squared diameters turned upside down will be to each other as the yarn numbers. This holds just as true of the pieces of actual yarn as it does of the imaginary pieces of smooth round wood, for it makes no difference whether the diameter can be measured readily, or whether the standard length is long or short, *the yarn numbers are inversely proportional to the squares of the yarn diameters*. Expressed in a formula this is

$$\text{No.} = \frac{\text{Constant}}{\text{Dia.}^2}.$$

Transforming,

$$\text{Dia.}^2 = \frac{\text{Constant}}{\text{No.}} \quad \ldots\ldots\ldots \quad (5)$$

But from equation (4)

$$\text{Dia.} \times \text{Cut} = \text{Constant},$$

$$\text{Dia.}^2 = \frac{\text{Constant}}{\text{Cut}^2} \quad \ldots\ldots\ldots \quad (6)$$

(6) – (5) $$\frac{\text{Constant}}{\text{No.}} = \frac{\text{Constant}}{\text{Cut}^2},$$

Inverting

$$\text{No.} = \frac{\text{Cut}^2}{\text{Constant}}.$$

Note that the constants are not changed since their actual values are not yet required.

In other words, *the number of the yarn is proportional to the square of the cut.* This deduction was originally made by Gustav Willkomm. It follows naturally from his observation that the diameter of the yarn is proportional to the needle spacing.

Foundation Principles. — It has been shown from consideration of the individual rib stitch that stitches — and consequently fabrics — of the same characteristics are in every respect proportional to the diameter of the yarn from which they are formed and conversely that when the proportion of the height of the stitch to the diameter of the yarn is changed, the characteristics of the stitch and consequently of the fabric are changed. Since these are the foundation principles of knit fabrics, they should be thoroughly understood. The dependence of these basic principles on the diameter of the yarn makes the diameter of the yarn the foundation fact in knitting. There are other facts considered elsewhere, but the diameter leads in importance.

Changing the Characteristics of the Fabric. — To return to the foundation principles of the fabric it will be noticed *that there are as a rule with any one kind of yarn only two factors which may be changed, that is, the diameter of the yarn and the length of yarn in the stitch,* each of which influences the height of the loop and consequently the number of courses per inch; also that *the width of the wale and the thickness of the fabric are proportional to the diameter of the yarn* and independent of the length of the stitch except for extremes which are considered elsewhere.

Three General Cases. — For this discussion the following combinations are considered:

1. Stitches per foot of yarn constant, yarn diameter varied.
2. Stitches per foot of yarn varied, yarn diameter constant.
3. Stitches per foot of yarn and yarn diameter varied so that the stitches per foot multiplied by the yarn diameter equals a constant — i.e., the stitches per foot increase just as the diameter decreases.

What Determines Good Fabric. — Nos. 1 and 2 are readily understood. No. 3 is the condition for fabrics of different fineness but of the same characteristics. In other words, if a lot of machines from the coarsest to the finest were started in a community of practical knitters and the fabrics were compared after the machines were in commercial operation, it would be found that the product of the stitches per foot of yarn multiplied by the yarn diameter would be one and the same constant for all of the fabrics, of course with slight variations. The reasons for this are that in any one community there is an idea of what characteristics are required for good fabric, whether coarse or fine, so the yarn and stitch would be so adjusted as to give these characteristics on the different cut machines, with the result that the product of the stitches per foot of yarn and the diameter of the yarn would be a certain constant, for this is the condition for fabrics of different fineness but of the same characteristics. Consequently, the third combination is the most important one, for it represents average knitting conditions, whereas combinations 1 and 2, which range from the extreme of impracticability of operation to that of instability of fabric, represent abnormal conditions generally and average conditions only between the limits of the range. However, their consideration is necessary in order to understand the subject.

Stitches per Foot Constant and Yarn Diameter Varied. (*The first case.*) — It is found by experiment that when the stitch is kept constant and the diameter of the yarn is varied, the courses and wales per unit of length change so that their product is a constant quantity. For instance, suppose that at a certain stitch and with a certain yarn the wales and courses are each 10 per inch. Then the product of the wales and courses is 100. If now the size of the yarn is either increased or diminished, the product of the courses and wales will still remain 100. But it has already been shown that the width of the wale changes in proportion to the diameter of the yarn, from which it is possible to determine the change in the wales, after which the change in the courses may be determined by dividing the number of wales per inch into the constant product of the wales and the courses. Suppose that the yarn is increased in diameter 10 per cent. Then the width of the wale will also be increased 10 per cent.

Relation of Wales and Courses. — Consequently, the number of wales per inch after the change will be 10 divided by 1.1, which is 9.09. Now divide 100, the constant product, by 9.09, the new number of wales, which gives 11, the new number of courses. This relation may be represented graphically as in Illustration 5, which shows a piece of cross-section paper with courses laid off on the left scale upward from the zero at the lower left corner, and wales laid off at the bottom from the same starting point toward the right. A horizontal line from the 10-course mark meets a vertical line from the 10-wale mark, making a square in the lower left corner of the paper, and a curve passes through the upper right corner of the square. This curve contains the intersections of all of the lines whose product is 100. The points in it are found by assuming different numbers of wales and dividing them into 100 to get the corresponding courses. After the

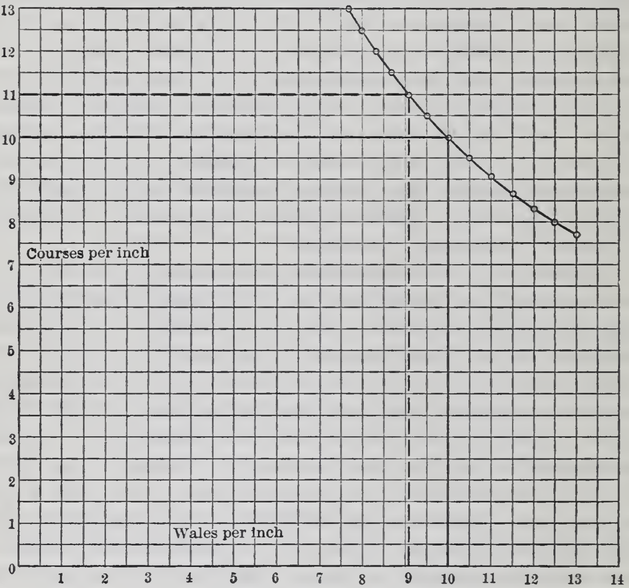


Illustration 5.

All rectangles with one corner at zero and the diagonally opposite corner in the curve contain the same number of stitches. This is the case with knit fabric when only the size of the yarn is changed. That is to say, for fabric from any machine, when only the yarn size is changed, the number of stitches per unit of area remains constant. In other words, changing only the yarn size makes no change in the number of stitches per square inch.

curve is obtained, when the number of courses (or wales) is known, the corresponding number of wales (or courses) is readily found by following the known number out to the curve and then reading the desired number from the other scale For instance, it has just been determined that after an increase in the diameter of the yarn of 10 per cent the number of wales per inch has changed from 10 to 9.09. Start from 9.09 wales and follow the dotted line out to the curve and then to the left to the course scale which it intersects at 11, the corresponding number of courses.

Product of Wales and Courses Dependent on Stitches per Foot of Yarn. — It should be borne in mind that this curve holds only for one set of conditions of not only stitch but kind of yarn and machine. Change in any of these factors moves the curve toward or from the origin (the zero), but does not alter its form. For instance, if the stitch is made tighter — that is, if the number of stitches per foot is increased — then the curve will be moved farther to the right and upward, but it will be obtainable in the same way, namely, by dividing the constant product of wales and courses by the number of wales, which number is obtainable from the diameter of the yarn, and then marking the intersections of the corresponding wales and courses. The constant product is so far best obtained by experiment with the machine and the kind of yarn in question.

Diameter of Yarn and Stitches per Foot of Yarn Determine Characteristics of Fabric for any one Kind of Yarn. — It should be explained here that theoretically the machine has nothing to do with these considerations, but it has become so common to consider the dimensions of the fabric, i.e., wales, courses, etc., dependent on the machine, that confusion is likely to result from a sudden departure from that idea. A little reflection will show at once how erroneous the idea is. Hand knitting preceded machine knitting, and with hand needles there was not — nor is to-day — any such thing as needle spacing, consequently, there is no such thing as cut or gauge, and yet a big variety of yarn numbers and lengths of stitch were and are usable with hand knitting. This was evidently forgotten when machine knitting became common; and from the fact that a certain degree of fineness of fabric came from a certain degree of fineness of machine, the notion became popular that the cut of the machine determined the fineness of the fabric. This notion really has its foundation in the limitations of the machine rather than in its adaptation to any particular work. It is possible to conceive of an infinitely fine, but infinitely strong, needle drawing a very long loop in a very large roving, which roving would determine the width of the loop entirely independent of the needle. However, in practice there are no infinitely strong needles, so we do not meet such ideal machines. Consequently the diameter of the yarn has to be proportional to the needle spacing, from which has come the mistaken conclusion that the spacing of the needles determines the fineness of the fabric, whereas it is really determined by the diameter of the yarn.

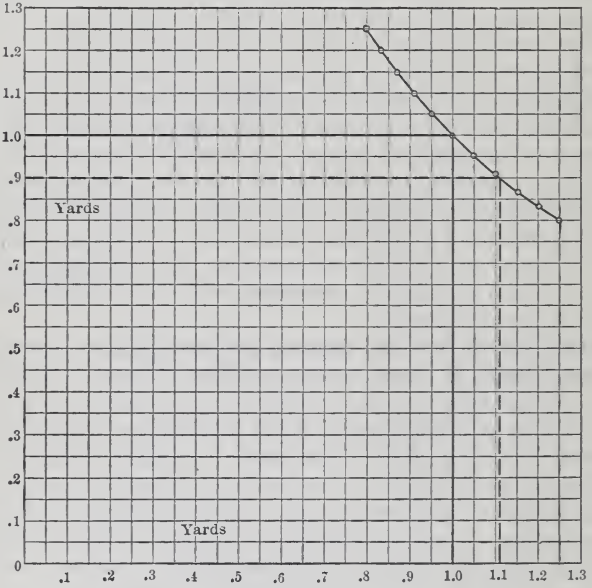


Illustration 6.

All rectangles with one corner at zero and the diagonally opposite corner in the curve have the same area. These rectangles represent the changes which take place in the fabric for changes in the diameter of the yarn, but no change in the number of needles, number of knitted courses, and number of stitches per foot of yarn. In other words, on a certain number of needles with a fixed length of loop, knit a certain number of courses with different sized yarn and every resulting piece of fabric will just fit under a curve of this character.

Relation of Width and Height of a given Piece of Fabric. — The relation of the wales and courses for stitches constant and yarn variable was shown on page 28. The relation of the width and height of a given piece of knit fabric for the same conditions may be similarly shown. Suppose that a piece of fabric is knit so that it is just one yard square. Moreover, suppose that the only change to be made is in the diameter of the yarn. Illustration 6 shows a chart similar to Illustration 5, except laid off on both scales in yards and tenths of yards. The square enclosed by the scale lines and the two lines drawn from 1 to the curve represents the square yard of cloth just mentioned. The curve is so drawn that it will contain the upper right corner of all rectangles whose area is one. Now make another piece of cloth the same as before, but with yarn 10 per cent larger in diameter. Since all conditions except the size of the yarn are the same, there will be the former total number of wales and courses. It is known that the wales will be wider in proportion to the increased diameter of the yarn, so this piece of fabric will be 1.1 yards in width. The height may be obtained by working through the wales and courses. The new number of wales per inch will be in the proportion of $\frac{1}{1.1} = 0.909$. Consequently, the new number of courses per inch will be in the proportion of $\frac{1}{0.909} = 1.10$. But since the number of courses is not changed, the height of the fabric will be 1 yard $\times \frac{1}{1.1} = 0.909$. The product of the width, 1.10, and the height, 0.909, is 1, consequently the piece of fabric will still contain one square yard, so that when it is drawn on the chart, its upper right corner will be in the curve as shown by the dotted lines. Comparing the wale and course chart, 5, with the square yard chart, 6, the observer sees that one is the reverse of the other, but that in each case the product of the dimensions is a constant.

Production in Square Yards. — From the above it follows that when the stitch is constant and the yarn is variable, the product of the width and the height of a piece of fabric (with the same number of stitches) is constant. *Therefore, the production in square yards of a knitting machine with stitches constant is independent of the yarn,* for what is gained in width by the use of larger yarn is lost in length by the drawing together of the courses. Moreover, *a square yard contains a constant length of yarn.*

Length of Yarn in a Square Yard of Fabric. — From the above, and since the (cotton) number of yarn is inversely proportional to the weight of a constant length, the weight per square yard goes up as the number of the yarn goes down, i.e., the product of the weight per square yard and the number of the yarn is a constant.

Proportioning Weight per Square Yard and per Dozen Garments. — When it is desired to change the weight of piece fabric per yard, or goods per dozen, the change of yarn may be calculated by the simple rule

Present weight × present yarn ÷ desired weight = desired yarn.

However, with garments care must be exercised to cut the same number of yards, which means that if the size of the yarn is increased, the sizes must be cut from smaller diameters of machine. It must be remembered, also, that the characteristics of the fabric will be changed, since the same characteristics are obtained only when the length of yarn in the stitch is proportional to the diameter of the yarn, which is the same as to say that the product of the diameter of the yarn and the stitches per foot of yarn is a constant.

Diameter of Yarn Constant, Stitches per Foot of Yarn Varied. — *The Second Case.* Experiments show that the courses vary in some proportion to the stitches per foot, that is to say, as the stitches per foot are increased the courses increase. The wales, of course, remain constant. Therefore, the weight per yard is increased, but not in the proportion in which the courses are increased, because the increase in the stitches per foot lessens the length of yarn in a course. Consequently the increase in weight per yard is a slow differential between the gain in weight due to increased courses and the loss due to decreased length of yarn in a course. No simple expression for this change in weight has yet been found.

Regular Fabrics. — *The Third Case,* that in which the product of the stitches per foot and the diameter of the yarn is constant, is illustrated, regarding the wales, courses and stitches by Illustration 7, with wales on the left scale and courses on the bottom scale. Several curves representing the constant products of wales and courses for different stitches are shown. The 45-degree diagonal drawn through the origin upward to the right is the dividing line for wales equal to courses. It will be noticed that as the wales increase the courses increase equally, but the stitches per foot must increase also. This fabric is looser than is generally considered desirable in America, where the courses and wales are in the proportion of about 12.5 to 10, which proportion is used in this book. The line representing it is just below the diagonal. However, the selection of any proportion is largely a matter of choice. The main fact is that for corresponding fabrics the stitch must be proportional throughout. This simple condition makes possible the use of a remarkable number of simple equations which are useful for showing not only

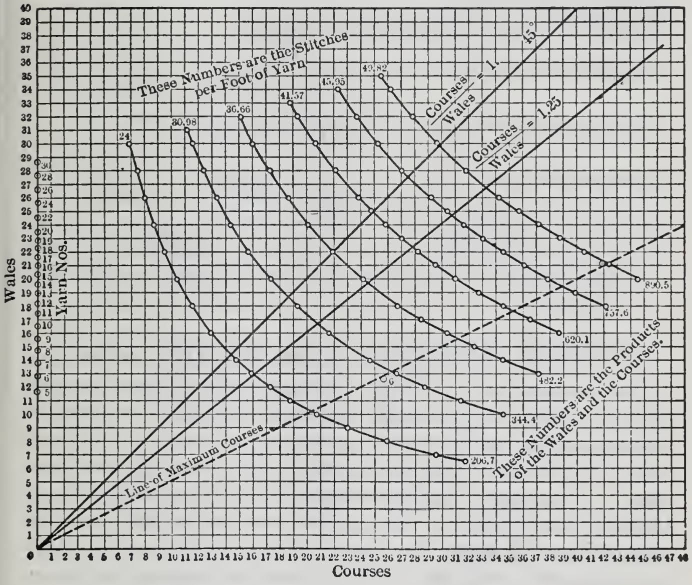


Illustration 7.

Chart showing the relation of wales, courses, and stitches in fabrics of the same characteristics.
The wales per inch increase as the diameter of the yarn decreases.
The courses per inch are proportional to the wales per inch.
The stitches per foot of yarn are proportional to the wales per inch.

the proportionate results of a change, but also the concrete results, so that knitting moves from a rule-of-thumb stage — rather a no-rule stage — to one of comparative certainty. Elsewhere are given fairly complete sets of rules showing the relations of all of the ordinary dimensions used in knitting. They are based on the principles just explained and on constants derived from measurement of some 200 samples of ribbed fabric made of carded mule-spun hosiery yarn. Among the important rib-fabric relations may be noted here the following, although the reader is referred to page 36 which gives the conditions on which the relations are based, and to pages 38 and 39 which give enough relations for ordinary requirements.

Some Relations of Regular Rib Fabrics. —

$$\text{Cut of machine} = \frac{1}{8.57 \text{ Dia. of yarn}}.$$

$$\text{Stitches per foot of yarn} = \frac{1}{2.14 \text{ Dia. of yarn}}.$$

$$\text{Courses per inch} = \frac{1}{3.2 \text{ Dia. of yarn}}.$$

$$\text{Wt. per square yard} = 38 \text{ Dia. of yarn}.$$

Production, pounds per feed per 10 hours = 57,772 (Dia. of yarn.)^2.

Production, square yards per feed, per 10 hours = 1520 Dia. of yarn.

PRACTICAL VARIATIONS FROM KNITTING RULES

It is unnecessary to tell knitters that knitting is not an exact science. They know this so well that they have become extremists on the subject, so that they are inclined to discredit all rules. Consequently, before a rule receives practical consideration it is necessary for the sponsor to proclaim that he knows there are exceptions to it in spite of the adage that there are exceptions to all rules. So the practical variations which follow are mentioned with the double object of meeting the above necessity and of pointing out where exceptions may be most expected.

The Shape of Yarn. — Yarn is supposed to be round; but it may be almost any other shape, except angular or absolutely flat. Soft yarn is frequently preferable for knitting, and the softness is usually obtained by slack twist; so that instead of a compact cylindrical mass like that of six-cord thread, the yarn consists of a bundle of fibers slackly twisted together and easily susceptible to pressure distortions. However, the general form is cylindrical, and the fabric formed from it corresponds closely to what is expected from cylindrical elements, so it is permissible to consider the yarn cylindrical, if allowances are made for distortion from the cylindrical form. This distortion is practically proportional for similar conditions. For instance, suppose that owing to compression the width of a fabric is 10 per cent less than that calculated on the assumption that the thread is cylindrical. Then that proportion, 10 per cent less, is applicable to fabrics on other cuts made of the same kind of yarn with a stitch proportional to the diameter of the yarn. In other words, results based on cylindrical yarn are valuable as proportions, even when distortion of the yarn prevents use of the absolute values, provided the distortion is caused by similar conditions.

Resilience or Resistance to Bending. — The structure of the knit stitch depends on resistance to bending, the force of which keeps the wales together in normal fabrics. Evidently this force depends on the kind and condition of the fiber, the twist of the yarn and other factors. Also, it depends on the curvature to which the yarn is subjected. An abrupt curve is resisted more than an easy one. The normal knitting curve has a radius of approximately $1\frac{1}{2}$ diameters of yarn. If the loop is so long that this radius is much increased, there will not be enough force to hold the loops closed, so that the width will increase rapidly, the elasticity will decrease and the fabric will become shapeless. At the other extreme of stitch, that is very tight, the curvature is shortened by lengthwise tension on the yarn which hugs the loops together, and narrows the fabric so that the loops lose their natural easy curves. The rules are not intended to apply to such fabrics, since they are so "sleazy" on the one hand and so "boardy" on the other that they comprise an insignificant part of knitting.

Most yarn used in knitting is susceptible of a sufficiently short bend to bring the wales together, but it can be realized that spring wire would not take such a bend, and that yarn of a wiry nature would take a bend between that of wire and that of soft cotton yarn. Accordingly, it is to be expected that fabrics made from wiry yarn will be wider than those made from the same size of soft cotton yarn. Sizing, dyeing, bleaching — in short, treatment of almost any kind — alters the bending property of yarn, so that allowance should be made therefor, when accuracy is required.

Stitch Distortion. — The popular impression is that the machine forms the stitch somewhat as a die forms a coin. But, ideally, the machine should draw through each other, loops of a proper length depending on the diameter of the yarn, and leave those loops to take the form dictated by their elasticity In actual practice there exists a wide range of stitches, from the ideal to those pulled far out of shape. This distortion may be caused by excessive take-up tension, by too tight a stitch for the yarn and cut, by improper clearing of the loops, etc. Some of these distortions are quite permanent, such as the widening of the fabric by a spread dial stitch; whereas others are not, such as the narrowing due to take-up tension, which narrowing disappears more or less quickly, according to the treatment to which the fabric is subjected after knitting.

There are other causes which make the actual results differ from the rules and for which allowance must be made when unusual accuracy is required. But knitting is no exception in this regard. Excepting mathematics, no science is exact, and knitting occupies an intermediate ground among the sciences (or scientific arts), since it is not so exact as some but more exact than others. Moreover, it will improve in exactness since the relations of cause and effect of these disturbing factors may be determined just as the general principles of knitting have been determined, so that rules may be made for the proper allowance under given conditions.

EXPLANATION OF FORMULAS FOR REGULAR RIB FABRICS

These formulas are based on the following relations:

Yarn number $= \frac{\text{Cut}^2}{6}.$

Stitches per foot of yarn $= 4$ Cut.

Yarn diameter $= \frac{1}{21\sqrt{\text{No.}}}.$

Courses ÷ Wales $= 1.25.$

Tensile strength of thread $= 6000\ (\text{diameter})^2.$

Diametral revolutions per minute = 700 (35 r.p.m. of a 20-inch cyl.).

This table is meant for the practical knitter, so the explanation is addressed especially to him.

The extreme left-hand column, No. 1, gives details of rib fabric about which the knitter should have definite knowledge. The other columns contain simple equations which give that knowledge expressed in as many different ways as the knitter may need, and many more than are ordinarily necessary. Therefore, it is essential that he should know which are the most important. A brief review of some of them will help him to decide.

Consider first the column headed $\frac{1}{2}$ Coils (No. 2) which means the number of close coils of yarn per half inch, such as it is recommended to practice getting by coiling the yarn on a watch-chain bar. The importance of learning this simple method of determining the size of yarn should be understood. If a geologist is given a little piece of rock he is supposed to be able to tell what it is and what can be done with it without asking a lot of questions about it. But if the knitter is given a piece of yarn, he has to ask what number it is, or ask for a larger piece and a yard stick (or reel) and scales before he can do anything but guess about it, and even after he does know the number, he is more learned than the average knitter if he can tell what fabric knit from it will look like, how much it will weigh per yard, how many pounds and square yards can be produced per day, etc. This $\frac{1}{2}$-Coil column puts all this information right into his hands, provided he puts the formulas into practice, for it takes practice to use formulas accurately, just as it does to shoot on the wing accurately. The knitter who does not use his formulas before he needs them will not make a better showing than the hunter who has not yet fired off his gun. It is hoped that every knitter who is interested will get a note book, put in it the $\frac{1}{2}$-Coil column (No. 2) and the No. column (No. 5) and put them to the test by coiling a piece of the yarn he is knitting, working out the results by the formulas and then comparing the theoretical results with the actual results. Only in this way can he learn one of the most important things about a practical formula, that is, the allowance to make in using it. One or two trials are not sufficient. Many are needed, but whoever makes them will be well repaid, for he can thereby get in a few days a fund of extremely useful knowledge much of which has heretofore been unavailable, and the balance of which has been obtainable only by years of experience.

The following explanations may be of use. They are given in order, starting at the head of the $\frac{1}{2}$-Coil column (No. 2).

The first two equations are self evident.

FORMULAS FOR

1	2	3	4	5	6	7
	½ Coils	Coils	Dia.	No.	Cut	Stitches per ft. of yarn
½ Coils	½ Coils	$\frac{\text{Coils}}{2}$	$\frac{1}{2\ \text{Dia.}}$	$10.5\sqrt{\text{No.}}$	4.2865 Cut	1.0716 S.
Coils	2×½ Coils	Coils	$\frac{1}{\text{Dia.}}$	$21\sqrt{\text{No.}}$	8.573 Cut	2.1433 S.
Dia.	$\frac{1}{2\times\frac{1}{2}\ \text{Coils}}$	$\frac{1}{\text{Coils}}$	Dia.	$\frac{1}{21\sqrt{\text{No.}}}$	$\frac{1}{8.573\ \text{Cut}}$	$\frac{1}{2.1433\ \text{S.}}$
No.	$\frac{(\frac{1}{2}\ \text{Coils})^2}{110.25}$	$\frac{\text{Coils}^2}{441}$	$\frac{1}{441\ \text{Dia.}^2}$	No.	$\frac{\text{Cut}^2}{6}$	$\frac{\text{Stitches}^2}{96}$
Cut	$\frac{\frac{1}{2}\ \text{Coils}}{4.2865}$	$\frac{\text{Coils}}{8.573}$	$\frac{1}{8.573\ \text{Dia.}}$	$2.4495\sqrt{\text{No.}}$	Cut	$\frac{\text{Stitches}}{4}$
Stitches per foot of yarn	$\frac{\frac{1}{2}\ \text{Coils}}{1.0716}$	$\frac{\text{Coils}}{2.1431}$	$\frac{1}{2.14325\ \text{Dia}}$	$9.798\sqrt{\text{No.}}$	4 Cut	Stitches
Wales per in.	$\frac{\frac{1}{2}\ \text{Coils}}{2}$	$\frac{\text{Coils}}{4}$	$\frac{1}{4\ \text{Dia.}}$	$5.25\sqrt{\text{No.}}$	2.1431Cut	$\frac{\text{Stitches}}{1.866}$
Courses per in.	$\frac{\frac{1}{2}\ \text{Coils}}{1.6}$	$\frac{\text{Coils}}{3.2}$	$\frac{1}{3.2\ \text{Dia.}}$	$6.5625\sqrt{\text{No.}}$	2.679 Cut	$\frac{\text{Stitches}}{1.4932}$
Wt. per sq. yd.	$\frac{18.987}{\frac{1}{2}\ \text{Coils}}$	$\frac{37.98}{\text{Coils}}$	37.98 Dia.	$\frac{1.808}{\sqrt{\text{No.}}}$	$\frac{4.43}{\text{Cut}}$	$\frac{17.72}{\text{Stitches}}$
Production 1 feed, 10 hrs. Lbs.	$\frac{14{,}443}{(\frac{1}{2}\ \text{Coils})^2}$	$\frac{57{,}772}{\text{Coils}^2}$	57,772 Dia.^2	$\frac{131}{\text{No.}}$	$\frac{786}{\text{Cut}^2}$	$\frac{12{,}576}{\text{Stitches}^2}$
Production 1 feed, 10 hrs. Sq. Yds.	$\frac{760.1}{\frac{1}{2}\ \text{Coils}}$	$\frac{1520.2}{\text{Coils}}$	1520.2 Dia.	$\frac{72.39}{\sqrt{\text{No.}}}$	$\frac{177.31}{\text{Cut}}$	$\frac{709.241}{\text{Stitches}}$
Tensile strength along wales, pounds per inch width, T	$\frac{3000}{\frac{1}{2}\ \text{Coils}}$	$\frac{6000}{\text{Coils}}$	6000 Dia.	$\frac{285.7}{\sqrt{\text{No.}}}$	$\frac{699.8}{\text{Cut}}$	$\frac{2799}{\text{Stitches}}$
Tensile strength along courses, pounds per inch width, t	$\frac{937.5}{\frac{1}{2}\ \text{Coils}}$	$\frac{1875}{\text{Coils}}$	1875 Dia.	$\frac{89.29}{\sqrt{\text{No.}}}$	$\frac{218.7}{\text{Cut}}$	$\frac{874.7}{\text{Stitches}}$

The quantities at the left of the table are

REGULAR RIB FABRICS

8 Wales per inch	9 Courses per inch	10 Wt. per yd.	11 Production, 1 feed, 10 hours Pounds	12 Sq. yds.	Tensile strength along wales, pounds per inch width, T	Tensile strength along courses, pounds per inch width, t
2 Wales	1.6 Courses	$\frac{18.987}{\text{Wt. sq. yd.}}$	$\frac{120.17}{\sqrt{\text{Pounds}}}$	$\frac{760.1}{\text{Sq. yds.}}$	$\frac{3000}{T}$	$\frac{937.5}{t}$
4 Wales	3.2 Courses	$\frac{37.98}{\text{Wt. sq. yd.}}$	$\frac{240.36}{\sqrt{\text{Pounds}}}$	$\frac{1520.2}{\text{Sq. yds.}}$	$\frac{6000}{T}$	$\frac{1875}{t}$
$\frac{1}{4\text{ Wales}}$	$\frac{1}{3.2\text{ Courses}}$	$\frac{\text{Wt. sq. yd.}}{37.98}$	$\frac{\sqrt{\text{Pounds}}}{240.36}$	$\frac{\text{Sq. yds.}}{1520.2}$	$\frac{T}{6000}$	$\frac{t}{1875}$
$\frac{\text{Wales}^2}{27.56}$	$\frac{\text{Courses}^2}{43.06}$	$\frac{3.269}{(\text{Wt. per yd.})^2}$	$\frac{131}{\text{Pounds}}$	$\frac{5240}{(\text{Sq.yds.})^2}$	$\frac{81{,}625}{T^2}$	$\frac{7973}{t^2}$
$\frac{\text{Wales}}{2.1431}$	$\frac{\text{Courses}}{2.679}$	$\frac{4.43}{\text{Wt. per yd.}}$	$\frac{28.035}{\sqrt{\text{Pounds}}}$	$\frac{177.31}{\text{Sq. yds.}}$	$\frac{699.8}{T}$	$\frac{218.7}{t}$
1.866 Wales	1.4932 Courses	$\frac{17.72}{\text{Wt. per yd.}}$	$\frac{112.14}{\sqrt{\text{Pounds}}}$	$\frac{709.24}{\text{Sq. yds.}}$	$\frac{2799}{T}$	$\frac{874.7}{t}$
Wales	$\frac{\text{Courses}}{1.25}$	$\frac{9.495}{\text{Wt. per yd.}}$	$\frac{60.08}{\sqrt{\text{Pounds}}}$	$\frac{380.05}{\text{Sq. yds.}}$	$\frac{1500}{T}$	$\frac{468.75}{t}$
1.25 Wales	Courses	$\frac{11.868}{\text{Wt. per yd.}}$	$\frac{75.105}{\sqrt{\text{Pounds}}}$	$\frac{475}{\text{Sq. yds.}}$	$\frac{1875}{T}$	$\frac{585.9}{t}$
$\frac{9.495}{\text{Wales}}$	$\frac{11.868}{\text{Courses}}$	Wt.	$\frac{\sqrt{\text{Pounds}}}{6.3305}$	$\frac{\text{Sq. yds.}}{40.04}$	$\frac{T}{157.9}$	$\frac{t}{49.34}$
$\frac{3610}{\text{Wales}^2}$	$\frac{5641}{\text{Courses}^2}$	40.075 Wt.^{2}	Pounds	$\frac{(\text{Sq.yds.})^2}{40.04}$	$\frac{T^2}{623.48}$	$\frac{t^2}{60.92}$
$\frac{380.05}{\text{Wales}}$	$\frac{475}{\text{Courses}}$	40.04 Wt.	$6.3245\sqrt{P}$	Yds.	$\frac{T}{3.947}$	$\frac{t}{1.2335}$
$\frac{1500}{\text{Wales}}$	$\frac{1875}{\text{Courses}}$	157.9 Wt.	$24.97\sqrt{P}$	3.947 Sq. yds.	T	$3.2\,t$
$\frac{468.75}{\text{Wales}}$	$\frac{585.9}{\text{Courses}}$	49.34 Wt.	$7.804\sqrt{P}$	1.2335 × Sq. yds.	$\frac{T}{3.2}$	t

expressed in terms of those at the top.

Regular Rib Fabrics

Square root of yarn number	½ Coils per in. Maximum No. of courses	Coils per in.	Yarn dia.	Yarn No.	Cut	Stitches per foot of yarn	Wales per in. Thicknesses per in.	Courses per in.	Wt. sq. yd.	Production per feed, 10 hours, 700 diametral r.p.m.		Thickness
										Pounds	Sq. yds.	
2.236	23.5	47	.021295	5		21.91	11.74	14.67	.8087	26.2	32.37	.08518
2.45	25.7	51.5	.019441	6	6	24	12.86	16.08	.7380	21.834	29.54	.07777
2.646	27.8	55.6	.017998	7		25.92	13.89	17.36	.6834	18.715	27.36	.07199
2.828	29.7	59.4	.016835	8	7	27.71	14.85	18.56	.6394	16.375	25.60	.06734
3	31.5	63	.015873	9		29.39	15.75	19.69	.6028	14.556	24.13	.06350
3 162	33.2	66.4	.015057	10		30.98	16.63	20.75	.5719	13.100	22.89	.06023
3.317	34.8	69.7	.014357	11	8	32.5	17.44	21.77	.5451	11.908	21.82	.05743
3.464	36.4	72.8	.013746	12		33.94	18.19	22.73	.5220	10.916	20.89	.05498
3.606	37.9	75.7	.013207	13		35.32	18.93	23.66	.5014	10.770	20.07	.05283
3.742	39.3	78.6	.012725	14	9	36.66	19.65	24.56	.4832	9.357	19.34	.0509
3.873	40.7	81.3	.012294	15		37.94	20.34	25.42	.4669	8.733	18.69	.04918
4	42	84	.011904	16		39.19	21	26.25	.4521	8.188	18.1	.04762
4.123	43.2	86.4	.011567	17	10	40.34	21.61	27.06	.4386	7.706	17.55	.04627
4.243	44.6	89.1	.011223	18		41.57	22.28	27.84	.4262	7.278	17.06	.04490
4.359	45.8	91.5	.010925	19		42.7	22.88	28.6	.4148	6.895	16.60	.04370
4.472	47	93.9	.010646	20	11	43.8	23.48	29.34	.4044	6.550	16.18	.04258
4.583	48.1	96.2	.010391	21		44.9	24.06	30.07	.3946	6.238	15.78	.04156
4.690	49.3	98.5	.010152	22		45.95	24.63	30.78	.3855	5.954	15.43	.04062
4.796	50.4	100.7	.009929	23		46.98	25.18	31.47	.3770	5.696	15.09	.03972
4.900	51.4	102.9	.009720	24	12	48	25.72	32.16	.3690	5.459	14.77	.03888
5.000	52.5	105	.009523	25		48.99	26.25	32.81	.3617	5.240	14.48	.03809
5.100	53.4	106.8	.009366	26		49.82	26.69	33.47	.3546	5.039	14.19	.03747
5.200	54.6	109.1	.009164	27		50.91	27.28	34.12	.3477	4.852	13.92	.03666
5.292	55.6	111.1	.008999	28	13	51.84	27.78	34.74	.3417	4.678	13.68	.03600
5.385	56.5	113.1	.008843	29		52.76	28.27	35.34	.3358	4.517	13.44	.03537
5.477	57.5	115	.008694	30		53.66	28.75	35.94	.3303	4.367	13.21	.03478
5.568	59.4	117	.008553	31		54.55	29.23	36.54	.3248	4.226	13	.03422
5.657	60.3	118.8	.008418	32		55.42	29.7	37.15	.3197	4.094	12.79	.03367
5.745	61.2	120.7	.008290	33	14	56.28	30.16	37.7	.3148	3.970	12.6	.03316
5.831	62.1	122.5	.008167	34		57.12	30.63	38.27	.3101	3.853	12.41	.03267

Diameter of Yarn. — This is useful to know, although it is not expected that the practical knitter will do much calculating with the diameter, since the coils per half inch are more convenient.

Number of Yarn. — This is very important, but the user should remember that it does not always give the exact number which is obtained by weighing. Of what use is it then? Of much more use than the regular number, which is of use principally for the pounds production and pounds per yard, whereas the number determined by the diameter is the one which concerns the running of the machine, the wales, the courses, the width of the fabric, and the square-yard production, all of which are of far more importance to the knitter than the others. Count the coils in half an inch, multiply them together, and divide by 110. The quotient is the cotton number of the yarn. Do not worry about the decimal point, for experience will show whether the yarn is 2, 20, or 200. Practice by taking one short piece of yarn and coiling it several times to see what the average error is. One coil in twenty, over or under, is not enough to worry about. Some yarns cannot be coiled satisfactorily, such as thrown silk and very loosely-twisted worsted. But probably 95 per cent of the yarns used can be satisfactorily coiled, so the method should not be abandoned on account of its limitations until a superior one is found.

Notice that in the above calculation which gives the final result, a covenient approximation to the exact constant is used, namely, 110 instead of 110.25, which practice should be followed in every such case. But when these formulas are used for the derivation of other formulas the exact constants should be used in order to avoid discrepancies between the derived formulas.

Cut. — The correct cut (needles per inch) for a given yarn is a very important question in knitting. Formerly, before it could be answered at all, the number of the yarn had to be known, and not only that, but it had to be expressed in the yarn count with which the knitter was familiar. Then he could give an idea of the cut on which to use it in the light of his experience, but if the yarn did not happen to be just the number which he had used, he was very likely to misjudge since the number of yarn is very misleading as to its size. What knitter is there, who in order to find the relative size of two yarns, would go to the trouble of extracting the square roots of the numbers and comparing the reciprocals of the square roots? Not one in a hundred. Yet that is the simplest way of comparing the sizes of yarns. No wonder that the knitter in his search for simplicity should get the erroneous notion that the cut should be proportional to the yarn number. This seems reasonable, since the yarn gets finer as the number increases. But it has made trouble for lots of knitters who have tried to follow it, since when the user counted that in going from a No. 10 to a No. 40 he was getting yarn only one-fourth as large, in reality, it was half as large, and was breaking needles to an extent not indicated by the rule. But here is a rule — cut from $\frac{1}{2}$ coils — which makes the yarn diameter proportional to the size of the spaces through which the yarn has to go, which represents good average practice, and which is applicable without yarn numbers at all, provided a little piece of the yarn is at hand. It frequently happens that a knitter is shown a sample of yarn too small to reel and is asked if it is adaptable to his machines. Here is a method of answering the question quickly and decisively. Divide the coils in half an inch by 4.29 and the quotient is the cut which is generally used for knitting such yarn economically.

Stitches. — The stitches per foot of yarn, although not much used, are important and sometimes indispensable. A knitter is told to start some machines and having done so is criticized for not having used a different length of stitch. Probably neither he nor his critics were at fault, but each had been brought up to a different standard of fabric. Here, however, is a standard based on sufficiently wide observation to make it defensible. Of course, after the machines are started and it is decided what kind of fabric is required for the particular conditions, the stitch should be changed accordingly, but in the absence of special orders the knitter should have good reasons for what he does. Not only this rule for the stitches per foot but the other rules as well, are useful as a basis of understanding between the knitter and his superior. It is not essential that either agrees to the constants used. Indeed, it is expected that the rules will be modified to meet the local requirements, but in their present shape they mark a line from which an agreed departure may be made. One cause of serious confusion in the knitting business has been this lack of a common ground for understanding between a knitter from one section of the country and a superintendent from another, so that the knitter frequently had to go back where he came from.

Wales per Inch. — These are useful in determining what the fabric will look like, since the fineness of fabric is considered to be represented by the wales per inch. The wales are practically independent of the stitches and of the cut.

Courses per Inch. — These depend on both the diameter of the yarn and on the stitches per foot, with the result that they are not subject to very close calculation, since a little error in the yarn diameter or in the stitches per foot of yarn makes a considerable change in the courses. However, it is sometimes desirable to be able to tell what number of courses to expect.

Weight per Yard. — This is seldom used, except in the piece-goods business, probably because the means of obtaining it have been inconvenient. However, the tables and rules given in this book remove much of the difficulty, so there is now no good reason for not giving the weight per yard the attention which it deserves. It is useful in determining how many square yards make up a dozen of goods, and after that in determining the change in weight per dozen resulting from a change in weight per yard. Regular rib fabric made of No. 13 yarn (38 coils per half inch) weighs about half a pound to the square yard, as the equation shows (18.987 ÷ coils per one-half inch). Suppose it is made into garments weighing 7 pounds to the dozen. Unless the trimming is unusually heavy, it may be neglected. Then for the purposes of the mill, one dozen of the goods contains $7 \div 0.50 = 14$ square yards of fabric. Now, suppose the mill can buy at a bargain a lot of yarn coiling 36 to the half inch, about one number heavier; $19 \div 36 = 0.53$, the weight per square yard, which multiplied by 14 equals 7.42, which shows that if this yarn is used it will make the goods nearly half a pound per dozen heavier, provided the regular stitch is used. (Stitches = $\frac{1}{2}$ Coils ÷ 1.07.) Many other problems like this, which should be calculated instead of guessed, may be calculated by the use of the simple rule for the weight of regular rib fabrics.

Production in Pounds per Ten Hours per Feed. — This is an extremely useful formula, since the ordinary method of working out production is too laborious for a busy knitter, yet he is frequently asked how many pounds per day can be produced with yarn like a given sample. Divide 14,443 by the coils in half an inch squared; or divide 14,443 by the coils in half an inch and then divide the quotient by them again. Suppose there are 30 coils per half inch. The square of 30 is 900. The quotient of 14,443 ÷ 900 is 16, the pounds production per feed per 10 hours actual running time. The other calculation is 14,443 ÷ 30 = 4814, and divided by 30 again, equals 16. There is no allowance for lost time, but none need be made if the user knows that his machines are running somewhat above the expected 700 diametral revolutions per minute. If they are running around 770, a lost time allowance of 10 per cent is made by increased speed, so 16 pounds per feed may be taken as final. On the other hand, if the knitter wants to get the production down fine, he may get the exact lost time and the exact diametral revolutions and correct the 16 pounds per feed by the methods explained elsewhere. To be very exact he should use the production derived from the number of the yarn, Column 5, because the number is more reliable when weight is concerned, whereas the coils are more reliable when size is concerned.

The pounds-production formula is a good one to try on skeptics. Almost every one knows that rules are of different degrees of reliability. For instance, weather forecasts frequently go wrong, but the rule that every one must die is quite reliable. So it is with knitting rules. The rule for the number of courses per inch may go wide of the mark, but the pounds-production rule is absolute (provided no mistake has been made in its derivation). It is amusing, therefore, to hear some knitter remark, "Well, I tried that production rule, and it was wrong, just as I thought it would be." That is, the calculated and actual results disagreed, so the natural conclusion was that the rule must be wrong. But the rule is absolute, so the assumed factors were wrong. In other words, the experimenter did not get the speed, the yarn number, the stitch, and the time with the accuracy which he expected of the rule, so he jumped at the conclusion that the rule was wrong, thereby confessing his own error. If such mistakes are made in the use of absolute rules, they may also be made in the use of the rules which are admittedly approximate, so that these rules may be made to appear less reliable than they really are.

Square Yards Production. — This is sometimes called for, so the knitter should be prepared to give it, although it is much less used than the pounds production.

Government contracts sometimes specify tensile strength. For explanation of the strength formulas see Theory of Knit Fabrics.

Column No. 3 gives the quantities just discussed in terms of the coils per inch for use in calculations, but the knitter need not trouble with these since the coils per half inch are more convenient for him.

Column No. 4 is also for theoretical calculations more than for practical problems.

Column No. 5 is nearly or quite as necessary as Column No. 2, since the knitter should be able to know what he can do with yarn which he has not seen, as well as with yarn of which he has a sample, provided, of course, that the twist or the material does not make it unsuitable for knitting. This column gives what Column No. 2 does but in terms of the yarn number. The remarks already made apply to this column, so it is not necessary to repeat them.

The other columns are useful to the investigator, analyst, and designer more than to the practical knitter, so he need not trouble with them, although in casually reading them over he may see one or more expressions adapted to his special requirements.

EXPLANATION OF REGULAR FLAT-FABRIC FORMULAS. — LOOP-WHEEL

These formulas are based on the following:

Yarn number $= \frac{\text{Gauge}^2}{40}$.

Stitches per foot = 3.0983 Gauge.

Yarn diameter $= \frac{1}{21\sqrt{\text{No.}}}$.

Courses ÷ Wales = 1.25.

Tensile strength of thread = 6000 Dia^2.

Diametral revolutions per minute = 1000 (50 r.p.m. of a 20-inch cyl.)

Fifty revolutions per minute of a 20-inch cylinder is lower speed than is used in many places, but since wool work and fine

1	2	3	4	5	6	7
	½ Coils	Coils	Dia.	No.	Cut	Gauge
½ Coils	½ Coils	$\frac{\text{Coils}}{2}$	$\frac{1}{2\text{ Dia.}}$	$10.5\sqrt{\text{No.}}$	2.49 Cut	1.66 Ga.
Coils	2×½ Coils	Coils	$\frac{1}{\text{Dia.}}$	$21\sqrt{\text{No.}}$	4.98 Cut	3.32 Ga.
Dia.	$\frac{1}{2\times\frac{1}{2}\text{ Coils}}$	$\frac{1}{\text{Coils}}$	Dia.	$\frac{1}{21\sqrt{\text{No.}}}$	$\frac{1}{4.98\text{ Cut}}$	$\frac{1}{3.32\text{ Ga.}}$
No.	$\frac{(\frac{1}{2}\text{ Coils})^2}{110.25}$	$\frac{\text{Coils}^2}{441}$	$\frac{1}{441\text{ Dia.}^2}$	No.	$\frac{\text{Cut}^2}{17.78}$	$\frac{\text{Ga.}^2}{40}$
Cut	$\frac{\frac{1}{2}\text{ Coils}}{2.49}$	$\frac{\text{Coils}}{4.98}$	$\frac{1}{4.98\text{ Dia.}}$	$4.2165\sqrt{\text{No.}}$	Cut	⅔ Gauge
Gauge	$\frac{\frac{1}{2}\text{ Coils}}{1.66}$	$\frac{\text{Coils}}{3.32}$	$\frac{1}{3.32\text{ Dia.}}$	$6.3245\sqrt{\text{No.}}$	$\frac{3}{2}$ Cut	Gauge
Stitches	$\frac{\frac{1}{2}\text{ Coils}}{.5358}$	$\frac{\text{Coils}}{1.0716}$	$\frac{1}{1.0716\text{ Dia.}}$	$19.596\sqrt{\text{No.}}$	4.6475 Cut	3.0983 Ga.
Wales per in.	$\frac{\frac{1}{2}\text{ Coils}}{2}$	$\frac{\text{Coils}}{4}$	$\frac{1}{4\text{ Dia.}}$	$5.25\sqrt{\text{No.}}$	1.245 Cut	$\frac{\text{Gauge}}{1.2047}$
Courses per in.	$\frac{\frac{1}{2}\text{ Coils}}{1.6}$	$\frac{\text{Coils}}{3.2}$	$\frac{1}{3.2\text{ Dia.}}$	$6.5625\sqrt{\text{No.}}$	1.5563 Cut	1.0375 Ga.
Wt. per sq. yd.	$\frac{9.494}{\frac{1}{2}\text{ Coils}}$	$\frac{18.987}{\text{Coils}}$	18.987 Dia.	$\frac{.904}{\sqrt{\text{No.}}}$	$\frac{3.813}{\text{Cut}}$	$\frac{5.717}{\text{Ga.}}$
Pounds per 10 hrs. per feed	$\frac{17{,}755}{(\frac{1}{2}\text{ Coils})^2}$	$\frac{71{,}020}{\text{Coils}^2}$	$71{,}020\times\text{Dia.}^2$	$\frac{161}{\text{No.}}$	$\frac{2862}{\text{Cut}^2}$	$\frac{6440}{\text{Ga.}^2}$
Sq. yds. per 10 hrs. per feed	$\frac{1869}{\frac{1}{2}\text{ Coils}}$	$\frac{3738}{\text{Coils}}$	3738 Dia.	$\frac{178}{\sqrt{\text{No.}}}$	$\frac{750.6}{\text{Cut}}$	$\frac{1125.9}{\text{Ga.}}$
Tensile strength along wales, pounds per inch width, T	$\frac{1500}{\frac{1}{2}\text{ Coils}}$	$\frac{3000}{\text{Coils}}$	3000 Dia.	$\frac{142.86}{\sqrt{\text{No.}}}$	$\frac{602.35}{\text{Cut}}$	$\frac{903.6}{\text{Ga.}}$
Tensile strength along courses, pounds per inch width, t	$\frac{937.5}{\frac{1}{2}\text{ Coils}}$	$\frac{1875}{\text{Coils}}$	1875 Dia.	$\frac{89.29}{\sqrt{\text{No.}}}$	$\frac{376.7}{\text{Cut}}$	$\frac{565}{\text{Ga.}}$

The quantities at the left of the table

8 Stitches	9 Wales per in.	10 Courses per in.	11 Wt. per sq. yd.	12 Pounds per 10 hrs. per feed	Sq. yds. per 10 hrs. per feed	Tensile strength along wales, pounds per in. width, T	Tensile strength along courses, pounds per in. width, t
5358 Stitches	2 Wales	1.6 Courses	$\frac{9.494}{\text{Wt.}}$	$\frac{133.25}{\sqrt{\text{Pounds}}}$	$\frac{1869}{\text{Sq. yds.}}$	$\frac{1500}{T}$	$\frac{937.5}{t}$
.0716 Stitches	4 Wales	3.2 Courses	$\frac{18.987}{\text{Wt.}}$	$\frac{266.5}{\sqrt{\text{Pounds}}}$	$\frac{3738}{\text{Sq. yds.}}$	$\frac{3000}{T}$	$\frac{1875}{t}$
$\frac{1}{.0716 \text{ Stitches}}$	$\frac{1}{4 \text{ Wales}}$	$\frac{1}{3.2 \text{ Courses}}$	$\frac{\text{Wt.}}{18.987}$	$\frac{\sqrt{\text{Pounds}}}{266.5}$	$\frac{\text{Sq. yds.}}{3738}$	$\frac{T}{3000}$	$\frac{t}{1875}$
$\frac{\text{Stitches}^2}{384}$	$\frac{\text{Wales}^2}{27.56}$	$\frac{\text{Courses}^2}{43.06}$	$\frac{.81725}{\text{Wt.}^2}$	$\frac{161}{\text{Pounds}}$	$\frac{31{,}684}{(\text{Sq. yds.})^2}$	$\frac{20{,}411}{T^2}$	$\frac{7970}{t^2}$
$\frac{\text{Stitches}}{4.6475}$	$\frac{\text{Wales}}{1.245}$	$\frac{\text{Courses}}{1.5563}$	$\frac{3.813}{\text{Wt.}}$	$\frac{53.543}{\sqrt{\text{Pounds}}}$	$\frac{750.6}{\text{Sq. yds.}}$	$\frac{602.35}{T}$	$\frac{376.7}{t}$
$\frac{\text{Stitches}}{3.0983}$	$1.2047 \times$ Wales	$\frac{\text{Courses}}{1.0375}$	$\frac{5.717}{\text{Wt.}}$	$\frac{80.26}{\sqrt{\text{Pounds}}}$	$\frac{1125.9}{\text{Sq. yds.}}$	$\frac{903.6}{T}$	$\frac{565}{t}$
Stitches	$3.7325 \times$ Wales	$2.986 \times$ Courses	$\frac{17.72}{\text{Wt.}}$	$\frac{248.7}{\sqrt{\text{Pounds}}}$	$\frac{3490}{\text{Sq. yds.}}$	$\frac{2799.5}{T}$	$\frac{1749.6}{t}$
$\frac{\text{Stitches}}{3.7325}$	Wales	$\frac{\text{Courses}}{1.25}$	$\frac{4.747}{\text{Wt.}}$	$\frac{66.62}{\sqrt{\text{Pounds}}}$	$\frac{934.5}{\text{Sq. yds.}}$	$\frac{750}{T}$	$\frac{468.75}{t}$
$\frac{\text{Stitches}}{2.986}$	$1.25 \times$ Wales	Courses	$\frac{5.94}{\text{Wt.}}$	$\frac{83.27}{\sqrt{\text{Pounds}}}$	$\frac{1168.1}{\text{Sq. yds.}}$	$\frac{937.5}{T}$	$\frac{586}{t}$
$\frac{17.72}{\text{Stitches}}$	$\frac{4.747}{\text{Wales}}$	$\frac{5.94}{\text{Courses}}$	Wt. sq. yd.	$\frac{\sqrt{\text{Pounds}}}{14.036}$	$\frac{196.85}{\text{Sq. yds.}}$	$\frac{T}{157.89}$	$\frac{t}{98.75}$
$\frac{61{,}839}{\text{Stitches}^2}$	$\frac{4438}{\text{Wales}^2}$	$\frac{6935}{\text{Courses}^2}$	197.06 Wt.^2	Pounds	$\frac{(\text{Sq. yds.})^2}{196.9}$	$\frac{T^2}{127.23}$	$\frac{t^2}{49.57}$
$\frac{3490}{\text{Stitches}}$	$\frac{934.5}{\text{Wales}}$	$\frac{1168.1}{\text{Courses}}$	196.85 Wt.	$14.032 \times \sqrt{\text{Pounds}}$	Sq. yds.	$1.246\ T$	$1.99\ t$
$\frac{2799.5}{\text{Stitches}}$	$\frac{750}{\text{Wales}}$	$\frac{937.5}{\text{Courses}}$	157.89 Wt.	$11.26 \times \sqrt{\text{Pounds}}$	$\frac{\text{Sq. yds.}}{1.246}$	T	$1.6\ t$
$\frac{1749.6}{\text{Stitches}}$	$\frac{468.75}{\text{Wales}}$	$\frac{586}{\text{Courses}}$	98.75 Wt.	$7.038 \times \sqrt{\text{Pounds}}$	$\frac{\text{Sq. yds.}}{1.99}$	$\frac{T}{1.6}$	t

e expressed in terms of those at the top.

Regular Flat Fabrics

Square root of yarn No.	Thicknesses per in. Maximum No. of courses. ½ Coils per in.	Coils per in.	Yarn dia.	Yarn No.	Cut	Gauge	Stitches per foot of yarn	Wales per in.	Courses per in.	Wt. sq. yd.	Production per feed, 10 hours, 1000 diametral r.p.m.		Thickness.
											Pounds	Sq. yds.	
2.236	23.48	47	.0213	5		14	43.82	11.74	14.67	.4043	32.2	79.6	.0426
2.450	25.72	51.5	.0194	6	10	15	48.01	12.86	16.08	.369	26.83	74	.0389
2.646	27.78	55.6	.0180	7	11	17	51.85	13.89	17.37	.3416	23	67.27	.0356
2.828	29.7	59.4	.0168	8	12	18	55.42	14.84	18.56	.3196	20.13	62.94	.0337
3	31.5	63	.0159	9	13	19	58.78	15.75	19.69	.3013	17.89	59.34	.0317
3.162	33.207	66.4	.0151	10		20	61.96	16.60	20.75	.2859	16.1	56.3	.0301
3.317	34.825	69.7	.0144	11	14	21	65	17.41	21.77	.2725	14.64	53.66	.0287
3.464	36.375	72.8	.0137	12		22	67.88	18.19	22.73	.261	13.42	51.39	.0275
3.606	37.855	75.7	.0132	13	15	23	70.66	18.93	23.67	.2507	12.38	49.37	.0264
3.742	39.29	78.6	.0127	14		24	72.59	19.64	24.56	.2416	11.50	47.57	.0254
3.873	40.667	81.3	.0123	15	16		75.90	20.33	25.42	.2334	10.73	45.96	.0246
4	42	84	.0119	16	17	25	78.38	21	26.25	.226	10.06	44.5	.0238
4.123	43.225	86.5	.0116	17		26	80.80	21.65	27.06	.2193	9.47	43.17	.0231
4.243	44.55	89.1	.0112	18	18	27	83.15	22.28	27.85	.2130	8.94	41.95	.0224
4.359	45.762	91.5	.0109	19			85.42	22.89	28.61	.2074	8.47	40.84	.0218
4.472	46.965	93.9	.0106	20	19	28	87.63	23.48	29.35	.2021	8.05	39.8	.0213
4.583	48.115	96.2	.0104	21		29	89.8	24.06	30.08	.1972	7.67	38.84	.0208
4.690	49.25	98.5	.0102	22			90.32	24.62	30.78	.1927	7.32	37.95	.0203
4.796	50.357	100.7	.0099	23	20	30	93.98	25.18	31.47	.1885	7.00	37.11	.0198
4.899	51.44	102.9	.0097	24		31	96.2	25.72	32.15	.1845	6.71	36.33	.0194
5	52.503	105	.0095	25	21		97.98	26.25	32.81	.1808	6.44	35.6	.0190
5.099	53.380	106.8	.0094	26		32	99.92	26.77	33.46	.1773	6.19	34.91	.0187
5.196	54.56	109.1	.0092	27	22	33	101.83	27.28	34.10	.1740	5.96	34.26	.0183
5.292	55.56	111.1	.0090	28			103.7	27.78	34.73	.1708	5.75	33.67	.0180
5.385	56.54	113.1	.0088	29		34	105.5	28.27	35.34	.1678	5.55	33.05	.0177
5.477	57.51	115	.0087	30	23		107.3	28.76	35.94	.1650	5.37	32.5	.0174
5.568	58.46	116.9	.0086	31		35	109.1	29.23	36.54	.1623	5.19	31.97	.0171
5.657	59.395	118.8	.0084	32	24	36	110.9	29.70	37.12	.1598	5.03	31.47	.0168
5.745	60.31	120.6	.0083	33			112.57	30.16	37.70	.1573	4.88	30.98	.0166
5.831	61.223	122.5	.0082	34	25	37	114.26	30.61	38.27	.1550	4.74	30.53	.0163

balbriggan are made at about that speed, and since a comparatively low speed has been taken for latch-needle rib machines, namely, 700 diametral revolutions, the above loop-wheel speed is considered best for use here. Of course, flat-fleece machines run much faster than 1000 diametral revolutions, as do low-grade balbriggan machines, but it has been considered best to compromise on this speed rather than to use one which would not be so general. If time would allow, the best method would be to work out a complete set of formulas for each different set of established conditions. Until this is done, the reader must resort to modifying the conditions given, or to deriving his own formulas. The latter is much the better way, and it is not difficult since the laws are very simple.

Although this set of formulas is worked out especially for loop-wheel machines making flat work out of single cotton yarn, some of the formulas are applicable to other machines which conform to part of the conditions. For instance, the latch-needle automatic hosiery machine uses about the same weight of yarn as that used by the loop-wheel machine. Consequently the formulas for cut, stitches, weight per yard, and some others apply to the automatic hosiery machine, although of course the formula for pounds production does not, neither does that for yards production.

The explanation of the rib formulas applies equally to the flat formulas, so the reader is referred to that explanation and especially to that portion which shows the importance of Columns 2 and 5.

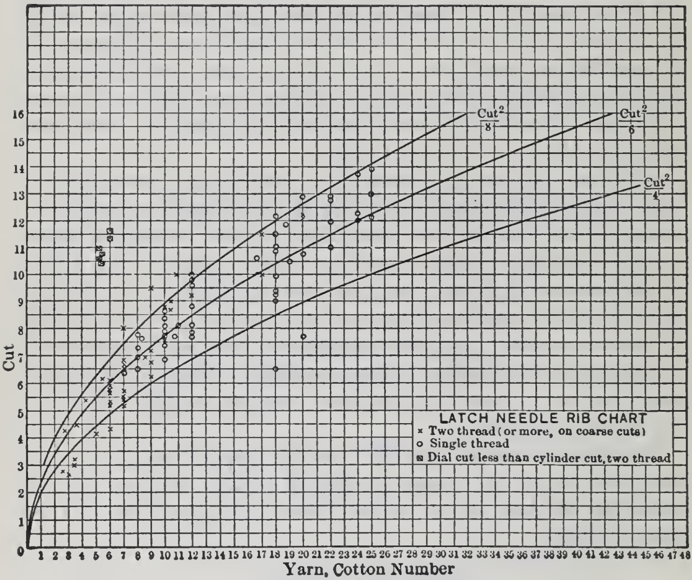
YARN-CUT RULES

Chart for Latch-needle Rib Machine

The cut or number of needles per inch is given on the left, the cotton number of the yarn is given at the bottom, and the three curves give the yarn number called for by the yarn rule, number equals cut squared divided by a constant, with constants respectively 8, 6 and 4, reading downward on the chart. Consequently the heavy-yarn limit is supposed to be represented by the highest curve, the average practice by the middle curve, and the limit for good fabric by the lower curve, although it is to be borne in mind that there is really no definite limit on the fine-yarn side.

The observations of actual practice are represented by marks, as follows: circles stand for single thread, crosses stand for double thread or more than double thread on coarse cuts, and crosses in squares stand for two-thread work where the dial had one-third the number of cuts that the cylinder had.

Evidently, when the dial is cut coarser than the cylinder, the



The relation between the yarn and the cut for latch-needle rib machines. The cut is on the left. The yarn number is at the bottom. The curves show the relations given by the rules for light, medium, and heavy yarn respectively. The crosses, squares, and circles are from actual practice irrespective of the rules.

rib rule does not hold, but the yarn may be much heavier. It is shown elsewhere that when the dial needles are removed entirely the yarn may be still heavier.

Three illustrations are evident of the use of yarn much heavier than the rule calls for, i.e., 7 yarn for 8 cut, 9 yarn for $9\frac{1}{2}$ cut and

11 yarn for 10 cut. However, all of these are the single equivalents of two threads, and show that it is practical to run two heavy threads where their single equivalent would not run. So the rule, Number = $Cut^2 \div 8$, may be taken as a reliable commercial guide for the heavy limit, except on course cuts as is shown below.

For 6 cut and coarser it is noticeable that the yarn is two thread. This is partially due to the practice where the observations were made. But in spite of the use of multiple threads, which favors heavy combined yarn weight, still some of the observations of actual practice fall below what any of the rules call for. This is true of all kinds of knitting machines so far investigated, consequently the yarn must be lighter than that called for by the rule for coarse cuts, say for 5 cut and coarser.

YARN-GAUGE RULES

Chart for Spring-needle Loop-wheel Machine

This chart gives a comparison of the yarn rules with actual practice, especially in order to show how much allowance should be made in using the rules.

The full lines represent the rules; and the squares, circles and crosses represent the actual practice. The square designates two-thread work with a short needle; the cross, two-thread work with an ordinary needle; and the circle, single-thread work with an ordinary needle.

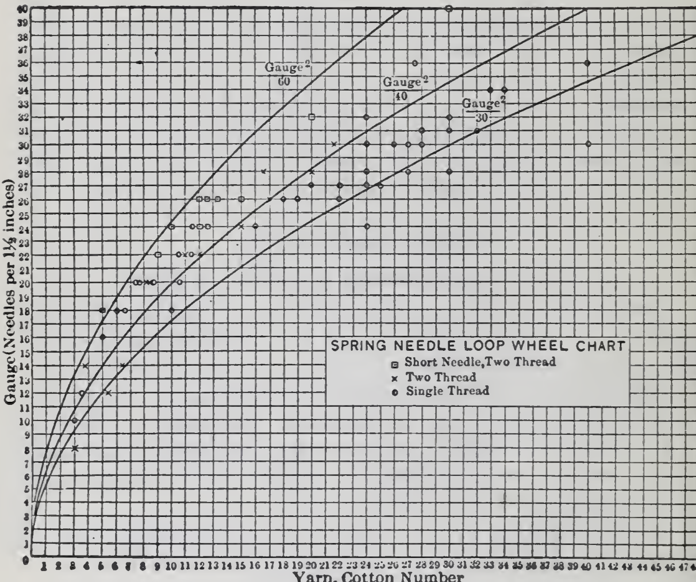
The significance of the chart may be understood from a specimen yarn reading, say, 24 gauge, which is as follows:

Condition	Yarn (or single equivalent of two yarns)
Heavy weight rule	9.6
Average rule	14.4
Light weight rule	19.2
Actual, two-thread, short needle	10, 12, 12.5
Actual, two-thread, ordinary needle	15
Actual, single-thread, ordinary needle	11.5, 16

The following points are important:

1. For 10 gauge and coarser, actual practice is to use yarn lighter than the rule calls for, on account of the improper design of coarse-gauge machines. Allowance should be made for this by using a smaller constant for 10 gauge and under.

For instance, if average weight fabric is desired, such as would be represented in medium gauges by yarn equal to gauge squared divided by 40, then for 8 and 10 gauge, divide by 30, and for finer gauges, divide by 25 or 20, according to the adaptability of the machine.



The relation between the yarn and the gauge for spring-needle loop-wheel circular machines. The gauge is on the left. The yarn number is at the bottom. The curves show the relations given by the rules for light, medium, and heavy yarn respectively. The crosses, squares, and circles are from actual practice irrespective of the rules.

2. Yarn equal to gauge squared divided by 60 seems to represent well the practical heavy limit. In this comparison only one case exceeds it, which is No. 5 yarn for 18 gauge. But this is the single equivalent of two yarns, and it is for a short needle, so it is extreme for an ordinary needle and single yarn.

3. The light weight rule, yarn equals gauge squared divided by 30, does not represent the light limit. This should be evident from the fact that for light yarn it is not the diameter but the strength which principally determines the limit. This rule does represent fairly well what is called light-yarn-short-stitch flat work generally used for fine balbriggans. Such fabrics are made in both odd and even gauges. It may be noticed that the single-thread practice for gauges 27, 28, 30 and 31, much of which is with high grade balbriggans, conforms closely to this rule.

Two-thread work follows the average rule or goes heavier except for 14 gauge and coarser.

Yarn Rules for Different Machines

	Average	Approximate heavy limit
Circular spring-needle rib	$\text{No.} = \frac{\text{Cut}^2}{10}$	
Circular latch-needle flat (work)	$\text{No.} = \frac{\text{Cut}^2}{13}$	
Straight jack sinker	$\text{No.} = \frac{\text{Gauge}^2}{56} = \frac{\text{Cut}^2}{24.89}$	
Automatic hosiery machines	$\text{No.} = \frac{\text{Cut}^2}{18}$	$\frac{\text{Cut}^2}{39}$
Circular spring-needle loop-wheel	$\text{No.} = \frac{\text{Gauge}^2}{40} = \frac{\text{Cut}^2}{17.77}$	$\frac{\text{Gauge}^2}{60}$ $\frac{\text{Cut}^2}{26.6}$
Latch-needle rib	$\text{No.} = \frac{\text{Cut}^2}{6}$	$\frac{\text{Cut}^2}{8}$

THE RELATION OF THE DIAMETER OF THE YARN TO THE NEEDLE SPACING

It should be evident that the yarn can be no wider than the space provided for it; and from this consideration, supported by observation of actual practice, Gustave Wilkomm long ago determined the average relation of yarn width to distance between centers of needles to be as 1 is to 7.4 for flat fabric. This was the introduction of science into knitting; consequently, the relation of the size of the yarn to the needle spacing is historically the most important knitting consideration. But although the room for the yarn is of interest and of importance, especially concerning the limit of the size of the yarn, other important factors should have consideration. A bridge designed to carry only the expected load would break under an overload. Just so a machine designed only for normal yarn would "smash" needles at a bunch or knot, both of which are frequent in commercial yarn. On the other hand, the yarn is generally flattened against the needle during the sinking of the stitch, so that it is sometimes possible to feed yarn which otherwise seems too big. From these considerations and from the fact that manufacturers differ in the yarn-space allowance for an equal distance between centers of needles, owing to the use of different-sized needles and sinkers, it is evident that for general purposes a more reliable basis of calculation is desirable.

Clearly, observation of use is the best means of determining usage. A certain kind of barge might be designed to carry a certain amount of load, but the best means of determining the capacity of that kind of barge would be by comparing observations of actual loads under different conditions. A load for smooth water might be about the calculated capacity, whereas for rough water it might be much less. The average capacity, which is the one desired, would be somewhere between the two just mentioned. So with the knitting machine the prospective user wants to know what size yarn he can safely run. Otherwise he might sell samples made of a trial lot of selected yarn, basing his knitting cost on the running of that yarn and then be under the necessity of delivering the goods from "bunchy" yarn with consequent extra cost for knitting, whereas if he had known what trouble would result, he could have made his samples with lighter yarn and so been better prepared to stand the overload due to an unexpected increase in the proportion of bunches. Indeed, there are so many such considerations which affect the size of the yarn with respect to the spacing of the needles that the only reliable means of allowing for them is by taking the results of actual practice. The constants of the yarn-cut rules given in this book are so obtained and although more extensive observation may modify them, still they are useful as given.

The form of these rules is yarn No. $= \frac{\text{Cut}^2}{k}$, in which k is the constant, equal to 6 for latch-needle rib machines, 18 for automatic hosiery machines, etc.

Since the formula contains the cut (which is the reciprocal of the needle spacing) and the yarn number, it gives all that is needed except the relation of the number of the yarn to its diameter, which is provided for single cotton hosiery yarn by

$$\text{No.} = \frac{1}{441 \text{ Dia.}^2}.$$

The relation of the diameter to the cut can now be derived as follows:

$$\text{No.} = \frac{\text{Cut}^2}{k}, \quad \ldots \ldots \quad (1)$$

$$\text{No.} = \frac{1}{441\ D^2}, \quad \ldots \ldots \quad (2)$$

$$(1) - (2) \qquad \frac{\text{Cut}^2}{k} = \frac{1}{441\ D^2}, \quad \ldots \ldots \quad (3)$$

$$\sqrt{(3)} \qquad \frac{\text{Cut}}{\sqrt{k}} = \frac{1}{21\ D},$$

$$D = \frac{\sqrt{k}}{21 \text{ Cut}}. \quad \ldots \ldots \quad (4)$$

That is, *the diameter of the yarn equals the square root of the yarn-cut-rule constant divided by twenty-one times the cut.*

Transforming (4),

$$D \times \text{Cut} = \frac{\sqrt{k}}{21},$$

$$D \div \frac{1}{\text{Cut}} = \frac{\sqrt{k}}{21}. \quad \ldots \ldots \quad (5)$$

Now $\frac{1}{\text{Cut}}$ is the needle spacing, i.e., in a ten-cut machine the needles are spaced $\frac{1}{10}$ inch apart. Consequently, $D \div \frac{1}{\text{Cut}}$ is the proportion of the needle spacing occupied by the yarn, which proportion equals $\frac{\sqrt{k}}{21}$, so that *the proportion of yarn diameter to needle spacing is the square root of the yarn-cut-rule constant divided by* 21.

Formula (4) for the loop-wheel machine becomes

$$D = \frac{1}{4.98 \text{ Cut}}$$

$$= \frac{1}{4.98} \times \frac{1}{\text{Cut}}$$

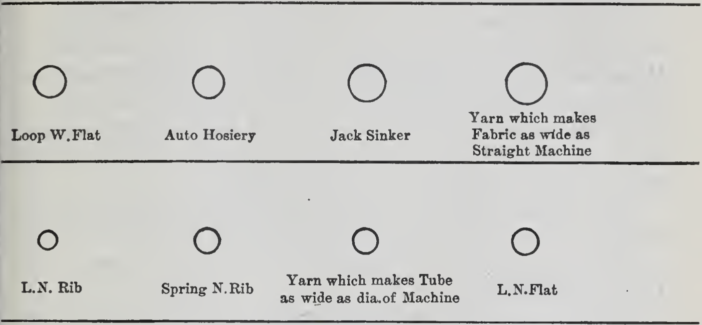
$$= \text{say, } \tfrac{1}{5} \times \text{Needle Spacing.}$$

Consequently, the yarn-diameter-cut formula for any machine shows the proportion of needle spacing occupied by the yarn diameter. The following table gives the above mentioned relations for several types of knitting machine.

1	2	3	4	5
Names of machines	Yarn-cut rules	Square root of yarn-cut rule constant $\sqrt{k}$	$\frac{21}{\sqrt{k}}$	Proportion of needle spacing occupied by yarn diameter $\frac{\sqrt{k}}{21}$
Hosiery, automatic........	$Cut^2 \div 18$	4.2425	4.948	.202
Latch-needle flat..........	$Cut^2 \div 13$	3.6055	5.824	.17167
Latch-needle rib...........	$Cut^2 \div 6$	2.4495	8.573	.11663
Spring-needle loop-wheel...	$Cut^2 \div 17.77$	4.2155	4.982	.20072
Spring-needle rib..........	$Cut^2 \div 10$	3.1623	6.640	.15059
Rule for flattened width of tube same as diameter of needle line.	$Cut^2 \div 11.17$	3.342	6.284	.15913
Straight jack-sinker machine	$Cut^2 \div 24.98$	4.989	4.209	.23745
Rule for fabric same width as length of needle line	$Cut^2 \div 27.56$	5.25	4	.25

Rules are given also for machines which produce fabric as wide as the machine, a rule for the circular machine and a rule for the flat machine. From this it is seen that for the circular machine, yarn with diameter $\frac{1}{6.28}$ of the needle spacing makes fabric as wide as the machine when the tube is flattened. Consequently, finer yarn makes fabric narrower than the machine and heavier yarn makes fabric wider than the machine. With the straight jack-sinker machine evidently the yarn must be $\frac{1}{4}$ of the needle spacing to make fabric as wide as the machine, since four diameters make a wale and the width of the wale must equal the needle spacing in order to have the fabric as wide as the machine (on the needle line). Yarn according to the average rule is $\frac{1}{4.21}$ of the needle spacing, which is very near to $\frac{1}{4}$.

This diagram shows graphically what Column 5 shows numerically.



The distance between adjacent lines represents the distance from center to center of needle (in one set, for rib machines).

The circles show the proportional diameter of yarn used on the machines named under them.

When the same-sized yarn is used on these different machines, the cut is inversely proportional to the diameters of these circles, so the latch-needle rib machine requires the coarsest cut.

WIDTH OF FLATTENED TUBE OF FABRIC FOR DIFFERENT NUMBERS OF NEEDLES AND YARN

As is demonstrated elsewhere, the theoretical width of the fabric does not depend directly on the diameter of the cylinder but on the diameter of the yarn and on the number of needles in the cylinder. The actual width differs from the theoretical width according to the extent of compression of the yarn, the distortion of the stitch, and the inaccuracy in determining the yarn diameter. Therefore, allowances must be made according to these conditions. In order to facilitate making these allowances, the numbers of needles used vary by twentieths, e.g., 200, 210, 220, etc. Consequently, if it is desired to make an allowance of 10 per cent more than the theoretical width, it may be done without calculating by reading the width two columns farther to the right than the nearest number of needles. If the allowance is to be 10 per cent less, the reading should be two columns to the left of the nearest number of needles. Inasmuch as exact results are not to be expected, the division of the needles by twentieths is close enough for practical purposes, since by using the number in the table nearest to the desired number the error cannot be over $2\frac{1}{2}$ per cent, which is closer than the diameter of the yarn can be measured.

It would be desirable to have a table from which the width of the fabric might be read at once, but this is an impossibility in the present state of knowledge. However, experience indicates that in any one mill with any one type of machine and kind of yarn, the variation from the theoretical width is quite regular, say 5 per cent or 10 per cent over or under. The variations from the table appear to be about as follows:

Small ribbers with a well-closed dial stitch and good take-up tension, 10 per cent less than the theoretical.

Rib body machines, without fabric ring, 10 per cent more than the theoretical.

Rib body machines, with fabric ring, same as the theoretical.

Loop-wheel flat-work machines, 10 per cent less.

Automatic hosiery machines, normal stitch, same as table.

Small latch-needle machine, flat work, very tight take-up tension, 30 per cent less.

Large latch-needle machine, flat work, 10 per cent less.

Cardigan lies out wider than corresponding plain rib from 43 per cent to 91 per cent, average 66 per cent.

Tuck lies out wider than corresponding plain rib from 42 per cent to 65 per cent, average 53 per cent.

Consequently, to get the width of either tuck or cardigan, determine the width of the plain rib fabric according to the table and the machine as given above, and then add, say 50 per cent for tuck, and 70 per cent for cardigan.

The above suggestions are not to be taken as final, since much more observation will be necessary for forming definite conclusions. Therefore, whoever has frequent need of determining the width of the fabric from the yarn and the number of needles should derive his own allowances by recording the differences between the table and the actual fabric, and then using the average difference for an allowance to be applied to the table. For instance, if the average of a number of observations is 10 per cent less than the table, and the extremes are 5 per cent either way, then the user may count with some certainty on coming within 5 per cent of the actual if he discounts the table by 10 per cent. Do not depend on memory for the determination of the correction, for gross errors are sure to result.

Folded Widths in Inches of Knit Fabric for Different Numbers of Yarn and Needles

Yarn, cotton No.	Needles in cylinder																			
	30	32	34	36	38	40	42	44	46	48	53	56	59	62	65	68	71	75	79	83
5	1.28	1.36	1.45	1.53	1.62	1.70	1.79	1.87	1.96	2.04	2.26	2.38	2.51	2.64	2.77	2.90	3.02	3.19	3.36	3.53
6	1.17	1.24	1.32	1.40	1.48	1.56	1.63	1.71	1.79	1.87	2.06	2.18	2.29	2.41	2.53	2.64	2.76	2.92	3.07	3.23
7	1.08	1.15	1.22	1.30	1.37	1.44	1.51	1.58	1.66	1.73	1.91	2.02	2.12	2.23	2.34	2.45	2.56	2.70	2.84	2.99
8	1.01	1.08	1.14	1.21	1.28	1.35	1.41	1.48	1.55	1.62	1.78	1.89	1.99	2.09	2.19	2.29	2.39	2.53	2.66	2.79
9	.95	1.02	1.08	1.14	1.21	1.27	1.33	1.39	1.46	1.52	1.68	1.78	1.87	1.97	2.06	2.16	2.25	2.38	2.51	2.63
10	.90	.96	1.02	1.08	1.14	1.20	1.26	1.32	1.39	1.45	1.60	1.69	1.78	1.87	1.96	2.05	2.14	2.26	2.38	2.50
11	.86	.92	.98	1.03	1.09	1.15	1.21	1.26	1.32	1.38	1.52	1.61	1.69	1.78	1.87	1.95	2.04	2.15	2.27	2.38
12	.82	.88	.93	.99	1.04	1.10	1.15	1.21	1.26	1.32	1.45	1.54	1.62	1.70	1.79	1.87	1.95	2.06	2.17	2.28
13	.79	.85	.90	.95	1.00	1.05	1.11	1.16	1.22	1.27	1.40	1.48	1.56	1.64	1.72	1.80	1.88	1.98	2.09	2.19
14	.76	.81	.87	.92	.97	1.02	1.07	1.12	1.17	1.22	1.35	1.43	1.50	1.58	1.65	1.73	1.81	1.91	2.01	2.11
15	.74	.79	.84	.89	.93	.98	1.03	1.08	1.13	1.18	1.30	1.38	1.45	1.52	1.60	1.67	1.75	1.84	1.94	2.04
16	.71	.76	.81	.86	.90	.95	1.00	1.05	1.10	1.14	1.26	1.33	1.40	1.48	1.55	1.62	1.69	1.79	1.88	1.98
17	.69	.74	.79	.83	.88	.93	.97	1.02	1.06	1.11	1.23	1.30	1.37	1.43	1.50	1.57	1.64	1.74	1.83	1.92
18	.67	.72	.76	.81	.85	.90	.94	.99	1.03	1.07	1.19	1.26	1.32	1.39	1.46	1.53	1.59	1.68	1.77	1.86
19	.66	.70	.74	.79	.83	.87	.92	.96	1.01	1.05	1.16	1.22	1.29	1.35	1.42	1.49	1.55	1.64	1.73	1.81
20	.64	.68	.72	.77	.81	.85	.89	.94	.98	1.02	1.13	1.19	1.26	1.32	1.38	1.45	1.51	1.60	1.68	1.77
22	.61	.65	.69	.73	.77	.81	.85	.89	.93	.97	1.08	1.14	1.20	1.26	1.32	1.38	1.44	1.52	1.60	1.69
24	.58	.62	.66	.70	.74	.78	.82	.86	.89	.93	1.03	1.09	1.15	1.21	1.26	1.32	1.38	1.46	1.54	1.61
26	.56	.60	.64	.67	.71	.75	.79	.82	.86	.90	.99	1.05	1.11	1.16	1.22	1.27	1.33	1.41	1.48	1.56
28	.54	.58	.61	.65	.68	.72	.76	.79	.83	.86	.95	1.01	1.06	1.12	1.17	1.22	1.28	1.35	1.42	1.49
30	.52	.56	.59	.63	.66	.70	.73	.77	.80	.83	.92	.97	1.03	1.08	1.13	1.18	1.23	1.30	1.37	1.44
32	.51	.54	.57	.61	.64	.67	.71	.74	.77	.81	.89	.94	.99	1.04	1.09	1.14	1.20	1.26	1.33	1.40
34	.49	.52	.56	.59	.62	.65	.69	.72	.75	.78	.87	.91	.96	1.01	1.06	1.11	1.16	1.23	1.29	1.36
36	.48	.51	.54	.57	.60	.64	.67	.70	.73	.76	.84	.89	.94	.98	1.03	1.08	1.13	1.19	1.25	1.32
38	.46	.49	.53	.56	.59	.62	.65	.68	.71	.74	.82	.86	.91	.96	1.00	1.05	1.10	1.16	1.22	1.28
40	.45	.48	.51	.54	.57	.60	.63	.66	.69	.72	.80	.84	.89	.93	.98	1.02	1.07	1.13	1.19	1.25

Folded Widths in Inches of Knit Fabric for Different Numbers of Yarn and Needles

Yarn, cotton No.	Needles in cylinder																			
	87	91	96	101	106	111	117	123	129	135	142	149	156	164	172	181	190	200	210	220
5	3.70	3.88	4.09	4.30	4.51	4.73	4.98	5.24	5.49	5.75	6.05	6.35	6.64	6.98	7.33	7.71	8.09	8.52	8.94	9.37
6	3.38	3.54	3.73	3.93	4.12	4.32	4.55	4.78	5.02	5.25	5.52	5.79	6.07	6.38	6.69	7.04	7.39	7.78	8.17	8.55
7	3.13	3.28	3.46	3.64	3.82	4.00	4.21	4.43	4.64	4.86	5.11	5.36	5.62	5.90	6.19	6.52	6.84	7.20	7.56	7.92
8	2.93	3.06	3.23	3.40	3.57	3.74	3.94	4.14	4.34	4.55	4.78	5.02	5.25	5.52	5.79	6.09	6.40	6.73	7.07	7.41
9	2.76	2.89	3.05	3.21	3.37	3.52	3.71	3.90	4.09	4.29	4.51	4.73	4.95	5.21	5.46	5.75	6.03	6.35	6.67	6.98
10	2.62	2.74	2.89	3.04	3.19	3.34	3.52	3.70	3.88	4.07	4.28	4.49	4.70	4.94	5.18	5.45	5.72	6.02	6.32	6.62
11	2.50	2.61	2.76	2.90	3.04	3.19	3.36	3.53	3.70	3.88	4.08	4.28	4.48	4.71	4.94	5.20	5.46	5.74	6.03	6.32
12	2.39	2.50	2.64	2.78	2.91	3.05	3.22	3.38	3.55	3.71	3.90	4.10	4.29	4.51	4.73	4.98	5.22	5.50	5.77	6.05
13	2.30	2.40	2.54	2.67	2.80	2.93	3.09	3.25	3.41	3.57	3.75	3.94	4.12	4.33	4.54	4.78	5.02	5.28	5.55	5.81
14	2.21	2.32	2.44	2.57	2.70	2.83	2.98	3.13	3.28	3.44	3.61	3.79	3.97	4.17	4.38	4.61	4.84	5.09	5.34	5.60
15	2.14	2.24	2.36	2.48	2.61	2.73	2.88	3.02	3.17	3.32	3.49	3.66	3.84	4.03	4.23	4.45	4.67	4.92	5.16	5.41
16	2.07	2.17	2.29	2.40	2.52	2.64	2.79	2.93	3.07	3.21	3.38	3.55	3.71	3.90	4.10	4.31	4.52	4.76	5.00	5.24
17	2.01	2.11	2.22	2.34	2.45	2.57	2.71	2.85	2.98	3.12	3.29	3.45	3.61	3.79	3.98	4.19	4.40	4.63	4.86	5.09
18	1.95	2.04	2.15	2.27	2.38	2.49	2.63	2.76	2.90	3.03	3.19	3.34	3.50	3.68	3.86	4.06	4.26	4.49	4.71	4.94
19	1.90	1.99	2.10	2.21	2.32	2.43	2.56	2.69	2.82	2.95	3.10	3.26	3.41	3.58	3.76	3.96	4.15	4.37	4.59	4.81
20	1.85	1.94	2.04	2.15	2.26	2.36	2.49	2.62	2.75	2.87	3.02	3.17	3.32	3.49	3.66	3.85	4.05	4.26	4.47	4.68
22	1.77	1.85	1.95	2.05	2.15	2.25	2.38	2.50	2.62	2.74	2.88	3.03	3.17	3.33	3.49	3.67	3.86	4.06	4.26	4.47
24	1.69	1.77	1.87	1.96	2.06	2.16	2.27	2.39	2.51	2.62	2.76	2.90	3.03	3.19	3.34	3.52	3.69	3.89	4.08	4.28
26	1.63	1.70	1.80	1.89	1.99	2.08	2.19	2.30	2.42	2.53	2.66	2.79	2.92	3.07	3.22	3.39	3.56	3.75	3.93	4.12
28	1.57	1.64	1.73	1.82	1.91	2.00	2.11	2.21	2.32	2.43	2.56	2.68	2.81	2.95	3.10	3.26	3.42	3.60	3.78	3.96
30	1.51	1.58	1.67	1.76	1.84	1.93	2.03	2.14	2.24	2.35	2.47	2.59	2.71	2.85	2.99	3.15	3.30	3.48	3.65	3.83
32	1.46	1.53	1.62	1.70	1.78	1.87	1.97	2.07	2.17	2.27	2.39	2.51	2.63	2.76	2.90	3.05	3.20	3.37	3.54	3.70
34	1.42	1.49	1.57	1.65	1.73	1.81	1.91	2.01	2.11	2.21	2.32	2.43	2.55	2.68	2.81	2.96	3.10	3.27	3.43	3.59
36	1.38	1.44	1.52	1.60	1.68	1.76	1.86	1.95	2.05	2.14	2.25	2.37	2.48	2.60	2.73	2.87	3.02	3.17	3.33	3.52
38	1.34	1.41	1.48	1.56	1.64	1.71	1.81	1.90	1.99	2.09	2.19	2.30	2.41	2.53	2.66	2.80	2.93	3.09	3.24	3.40
40	1.31	1.37	1.45	1.52	1.60	1.67	1.76	1.85	1.94	2.03	2.14	2.24	2.35	2.47	2.59	2.73	2.86	3.01	3.16	3.31

Folded Widths in Inches of Knit Fabric for Different Numbers of Yarn and Needles

Yarn, cotton No.	Needles in cylinder																			
	231	243	255	268	281	295	310	326	342	359	377	396	416	437	459	482	506	531	558	586
5	9.84	10.35	10.85	11.41	11.97	12.56	13.20	13.88	14.57	15.29	16.06	16.87	17.72	18.61	19.55	20.53	21.55	22.61	23.76	24.95
6	8.98	9.45	9.91	10.42	10.93	11.47	12.05	12.67	13.30	13.96	14.66	15.40	16.17	16.99	17.85	18.78	19.67	20.65	21.70	22.78
7	8.32	8.75	9.18	9.65	10.12	10.62	11.16	11.73	12.31	12.92	13.57	14.25	14.97	15.73	16.52	17.35	18.21	19.11	20.09	21.09
8	7.78	8.18	8.59	9.02	9.46	9.93	10.44	10.98	11.51	12.09	12.69	13.33	14.01	14.71	15.45	16.23	17.04	17.88	18.79	19.73
9	7.33	7.71	8.10	8.51	8.92	9.36	9.84	10.35	10.86	11.40	11.97	12.54	13.20	13.87	14.57	15.30	16.06	16.86	17.71	18.60
10	6.96	7.32	7.68	8.07	8.46	8.88	9.33	9.82	10.30	10.81	11.35	11.92	12.53	13.16	13.82	14.51	15 24	15.99	16.80	17.65
11	6.63	6.98	7.32	7.70	8.07	8.47	8.90	9.36	9.82	10.31	10.83	11.37	11.94	12.55	13.18	13.84	14.53	15.25	16.02	16.83
12	6.35	6.68	7.01	7.37	7.73	8.11	8.52	8.96	9.40	9.87	10.36	10.89	11.44	12.01	12.62	13.25	13.91	14.60	15.34	16.11
13	6.10	6.42	6.74	7.08	7.42	7 79	8.19	8.61	9.03	9.48	9.96	10.46	10.99	11.54	12.13	12.73	13.37	14.03	14.74	15.48
14	5.88	6.18	6.49	6.82	7.15	7.51	7.89	8.30	8.70	9.14	9.60	10.08	10.59	11.12	11.68	12.27	12.88	13.52	14.20	14.91
15	5.68	5.98	6.27	6.59	6.91	7.25	7.62	8.02	8.41	8.83	9.27	9.74	10.23	10.75	11.29	11.85	12.44	13.06	13.72	14.41
16	5.50	5.79	6.07	6.38	6.69	7.02	7.38	7.76	8.14	8.55	8.98	9.43	9.90	10.40	10.93	11.48	12.05	12.64	13.29	13.95
17	5.34	5.62	5.90	6.20	6.50	6.83	7.17	7.54	7.91	8.31	8.72	9.16	9.62	10.11	10.62	11.15	11.71	12.29	12.91	13.56
18	5.18	5.45	5.72	6.02	6.31	6.62	6.96	7.32	7.68	8.06	8.46	8.89	9.34	9.81	10.30	10.82	11.36	11.92	12.52	13.15
19	5.05	5.31	5.57	5.86	6.14	6.45	6.77	7.12	7.47	7.84	8.24	8.65	9.09	9.55	10.03	10.53	11.06	11.60	12.19	12.80
20	4.92	5.17	5.43	5.71	5.98	6.28	6.60	6.94	7.28	7.64	8.03	8.43	8.86	9.30	9.77	10.26	10.77	11.31	11.88	12.48
22	4.69	4.93	5.18	5.44	5.71	5.99	6.29	6.62	6.94	7.29	7.66	8.04	8.45	8.87	9.32	9.79	10.27	10.78	11.33	11.90
24	4.67	4.72	4.96	5.21	5.46	5.73	6.03	6.34	6.65	6.98	7.33	7.70	8.09	8.50	8.92	9.37	9.84	10.32	10.85	11.39
26	4.33	4.55	4.78	5.02	5.26	5.53	5.81	6.11	6.41	6.73	7.06	7.42	7.79	8.19	8.60	9.03	9.48	9.95	10.45	10.98
28	4.16	4.37	4.59	4.82	5.06	5.31	5.58	5.87	6.16	6.46	6.79	7.13	7.49	7.87	8.26	8.68	9.11	9.56	10.04	10.55
30	4.02	4.23	4.43	4.66	4.89	5.13	5.39	5.67	5.95	6.24	6.56	6.89	7.23	7.60	7.98	8.38	8.80	9.23	9.70	10.19
32	3.89	4.09	4.29	4.51	4.73	4.97	5.22	5.49	5.76	6.04	6.35	6.67	7.00	7.36	7.73	8.11	8.52	8.94	9.39	9.87
34	3.77	3.97	4.17	4.38	4.59	4.82	5.06	5.33	5.59	5.86	6.16	6.47	6.80	7.14	7.50	7.87	8.26	8.67	9.11	9.57
36	3.67	3.86	4.05	4.25	4.46	4.68	4.92	5.17	5.43	5.70	5.98	6.29	6.60	6.94	7.29	7.65	8.03	8.43	8.86	9.30
38	3.57	3.75	3.94	4.14	4.34	4.56	4.79	5.03	5.28	5.54	5.82	6.12	6.43	6.75	7.09	7.44	7.82	8.20	8.62	9.05
40	3.48	3.66	3.84	4.04	4.23	4.44	4.67	4.91	5.15	5.41	5.68	5.96	6.26	6.58	6.91	7.26	7.62	8.00	8.40	8.82

Folded Widths in Inches of Knit Fabric for Different Numbers of Yarn and Needles

Yarn, cotton No.	Needles in cylinder																	
	615	646	678	712	748	785	824	865	908	953	1001	1051	1104	1159	1172	1231	1293	1358
5	26.19	27.51	28.87	30.32	31.86	33.43	35.09	36.88	38.67	40.59	42.63	44.76	47.06	49.36	49.92	52.43	55.07	58.99
6	23.91	25.12	26.36	27.68	29.08	30.52	32.04	33.63	35.30	37.05	38 92	40.86	42.93	45.06	45.57	47.86	50.27	52.80
7	22.14	23.25	24.33	25.63	26.93	28.26	29.66	31.14	32.68	34.31	36.03	37.83	39.74	41.72	42.19	44.31	46.54	48.89
8	20.71	21.75	22.83	23.97	25.19	26.43	24.37	29.12	30.57	32.09	33.70	35.39	37.17	39.02	39.46	41.45	43.54	45.72
9	19.52	20.51	21.52	22.60	23.75	24.92	26.16	27.46	28.82	30.25	31.78	33.37	35.05	36.80	37.20	39.08	41.05	43.11
10	18.52	19.45	20.42	21.44	22.31	23.68	24.81	26.05	27.34	28.70	30.14	31.65	33.25	34.90	35.30	37.07	38.94	40.90
11	17.66	18.55	19.47	20.44	21.48	22.54	26.53	24.84	26.07	27.37	28.74	30.18	31.99	33.28	33.65	35.35	37.13	39.00
12	16.91	17.76	18.64	19.57	20.56	21.58	22.65	23.78	24.96	26.20	27.52	28.90	30.35	31.87	32.22	33.84	33.55	37.33
13	16.25	17.07	17.91	18.81	19.76	20.74	21.77	22.85	23.99	25.18	26.44	27.76	29.16	30.62	30.96	32.52	34.16	35.88
14	15.65	16.44	17.26	18.12	19.04	19.98	20.97	22.02	23.11	24.25	25.48	26.75	28.10	29.50	29.83	31.33	32.91	34.57
15	15.12	15.88	16.67	17.51	18.39	19.30	20.26	21.27	22.33	23.43	24.62	25.85	27.15	28.50	28.82	30.27	31.80	33.40
16	14.64	15.38	16.14	16.95	17.81	18.69	19.62	20.59	21.62	22.69	23.83	25.02	26.29	27.60	27.90	29.31	30.79	32.33
17	14.23	14.95	15.73	16.47	17.31	18.16	19.06	20.01	21.01	22.05	23.16	24.32	25.54	26.82	27.12	28.48	29.92	31.42
18	13.80	14.50	15.22	15.98	16.79	17.62	18.50	19.42	20.38	21.39	22.47	23.59	24.78	26.02	26.31	27.63	29.02	30.48
19	13.44	14.12	14.81	15.56	16.34	17.15	18.00	18.90	19.84	20.82	21.87	22.97	24.12	25.33	25.61	26.90	28.25	29.67
20	13.09	13.75	14.48	15.16	15.93	16.71	17.54	18.42	19.33	20.29	21.31	22.38	23.51	24.68	24.95	26.21	27.53	28.91
22	12.49	13.12	13.77	14.46	15.19	15.94	16.73	17.52	18.44	19.35	20.33	21.34	22.42	23.53	23.80	25.00	26.25	27.57
24	11.96	12.56	13.18	13.84	14.54	15.26	16.02	16.82	17.75	18.53	19.46	20.43	21.46	22.53	22.79	23.93	25.14	26.40
26	11.52	12.10	12.70	13.34	14.01	14.71	15.44	16.20	17.01	17.85	18.75	19.69	20.68	21.71	21.96	23.06	24.22	25.44
28	11.07	11.62	12.20	12.81	13.46	14.13	14.83	15.57	16.34	17.15	18.02	18.92	19.87	20.86	21.10	22.16	22.66	24.44
30	10.69	11.23	11.79	12.38	13.01	13.65	14.33	15.04	15.79	16.57	17.41	18.28	19.20	20.15	20.38	21.41	22.48	23.61
32	10.35	10.88	11.41	11.99	12.59	13.22	13.87	14.56	15.29	16.04	16.85	17.70	18.59	19.51	19.73	20.72	21.77	22.86
34	10.05	10.55	11.07	11.63	12.22	12.82	13.46	14.13	14.83	15.57	16.35	17.17	18.03	18.93	19.14	20.11	21.12	22.18
36	9.76	10.25	10.76	11.30	11.87	12.46	13.08	13.73	14.41	15.11	15.89	16.67	17.52	18.40	18.60	19 54	20.53	21.56
38	9.50	9.98	10.47	11.00	11.55	12.12	12.73	13.36	14.02	14.72	15.46	16.23	17.05	17.90	18.10	19.01	19.97	20.97
40	9.26	9.73	10.21	10.72	11.26	11.82	12.41	13.02	13.67	14.35	15.07	15.83	16.62	17.45	17.65	18.54	19.47	20.45

WIDTH OF FABRIC FROM DIFFERENT MACHINES

Consider a straight machine first. The cut is the number of needles per inch. Therefore, the distance from center to center of adjoining needles is $\frac{1}{\text{Cut}}$. If the wale is the same width as the distance from center to center of adjoining needles, then the fabric will be just as wide as the machine, i.e., just as wide as the length of needle line taken to produce it. But the wale is as wide as four times the diameter of the yarn. Therefore, the condition for fabric as wide as the machine is

$$4 \text{ Dia.} = \frac{1}{\text{Cut}},$$

or,

$$\text{Dia.} = \frac{1}{4 \text{ Cut}}.$$

Consequently *on a straight machine if the diameter of the yarn is equal to one divided by four times the cut, the fabric will be as wide as the needle line is long.*

The rule for the number of yarn to make fabric as wide as the machine is derived as follows:

From above, $$\text{Dia.} = \frac{1}{4 \text{ Cut}}, \quad \ldots \quad (1)$$

but $$\text{Dia.} = \frac{1}{21 \sqrt{\text{No.}}}. \quad \ldots \quad (2)$$

(2) − (1) $$\frac{1}{4 \text{ Cut}} = \frac{1}{21 \sqrt{\text{No.}}},$$

or $$\text{Cut} = 5.25 \sqrt{\text{No.}}$$

Squaring $$\text{No.} = \frac{\text{Cut}^2}{27.56}.$$

Which is to say, *on a straight machine if the number of the yarn is equal to the cut multiplied by itself and divided by 27.56, the fabric will be as wide as the needle line is long.*

The same considerations apply to the circular machine, with the added one that reduction must be made from the circular to the flat shape, since the diameter of the machine is used instead of the circumference to express its size. If the rule just given were followed, the fabric would lie out about $\frac{3}{2}$ as wide as the diameter of the machine, because it would be half as wide as the distance around the circumference of the machine. Consequently, the yarn should be only about two-thirds of the diameter which is required by the straight machine.

That diameter is

$$\text{(1)} \qquad \text{Dia.} = \frac{1}{4 \text{ Cut}}.$$

The ratio of the circumference of the circle to the diameter is 3.1416, so the diameter of the yarn should be multiplied by $\frac{2}{3.1416}$ in order to make the doubled width of the cloth the same as the diameter of the machine.

$$\frac{1}{4 \text{ Cut}} \times \frac{2}{3.1416} = \frac{1}{6.283 \text{ Cut}}.$$

Consequently, *on a circular machine if the diameter of the yarn equals one divided by 6.283 times the cut, the width of the flattened tube of fabric will equal the diameter of the needle line.*

But the diameter of the yarn $= \frac{1}{21 \sqrt{\text{No.}}}$;

therefore, $$\frac{1}{6.283 \text{ Cut}} = \frac{1}{21 \sqrt{\text{No.}}},$$

or $$\text{Cut} = 3.342 \sqrt{\text{No.}}$$

$$\text{No.} = \frac{\text{Cut}^2}{11.17}.$$

Or, in words, *on a circular machine if the number of the yarn is equal to the cut multiplied by itself and divided by 11.17, the width of the flattened tube of fabric will equal the diameter of the needle line.*

However, the size of the yarn is generally determined by more important considerations than the width of the fabric, such as its adaptability to economical knitting, the weight and appearance of the fabric, etc., so the rules based on general practice are the ones which should be used until other rules are shown to be as good. The demonstrations just given are not only useful for showing the general relation of the width of fabric and size of machine, but they may be used to calculate the width when the ordinary yarn rules are known.

The general form of the yarn rule is

$$\text{No.} = \frac{\text{Cut}^2}{k}.$$

Extract the square root of both sides of the equation

$$\sqrt{\text{No.}} = \frac{\text{Cut}}{\sqrt{k}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

But from (2)

$$\sqrt{\text{No.}} = \frac{1}{21 \text{ Dia. yarn}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

(3) − (4)

$$\frac{1}{21 \text{ Dia. yarn}} = \frac{\text{Cut}}{\sqrt{k}}.$$

But it is well known that the width of fabric from any one kind of machine is independent of the cut, since the same width of fabric is expected from any one diameter regardless of the

	Circular machines			Width of fabric (double) ÷ dia. of needle line
	Rule	Constant	$\sqrt{\text{Constant}}$	
Hosiery, automatic	$\frac{\text{Cut}^2}{18}$	18	4.2425	1.27*
Latch-needle, flat	$\frac{\text{Cut}^2}{13}$	13	3.6055	1.08
Latch-needle, rib	$\frac{\text{Cut}^2}{6}$	6	2.4495	.73
Spring-needle, loop-wheel	$\frac{\text{Cut}^2}{17.77}$	17.77	4.2155	1.26
Spring-needle, rib	$\frac{\text{Cut}^2}{10}$	10	3.1623	.95
General rule for fabric same width as circular machine	$\frac{\text{Cut}^2}{11.17}$	11.17	3.42	1
	Straight machines			Width of fabric (single) ÷ length of needle line
Straight jack-sinker	$\frac{\text{Cut}^2}{24.89}$	24.89	4.989	.95
General rule for fabric same width as flat machine	$\frac{\text{Cut}^2}{27.56}$	27.56	5.25	1

* Normal stitch.

cut, so the cut may be regarded as constant. Then the equation shows that the diameter of the yarn is proportional to the square root of the yarn-rule constant. Consequently, *the width of fabric from different machines is proportional to the square roots of their yarn-rule constants.* But we already know the rules for fabric of the same width as the machines; for instance, for circular machines with yarn No. $= \frac{\text{Cut}^2}{11.17}$ the fabric is just as wide as the machine. For latch-needle rib machines the regular constant is 6. The square root of 6 is 2.45 and the square root of 11.17 is 3.324. Since the square roots of the constants express the width of the fabric, and since 3.324 represents unit width, *the width of fabric to be expected from latch-needle rib machines is as 2.45 is to 3.324 or 0.73.* The table on page 65 shows this as well as the widths to be expected from other machines.

THE PRODUCTION OF CIRCULAR KNITTING MACHINES

Units of Production. — The production may be given in common units of measure, such as pounds, square yards, linear yards, etc., or in trade units, such as dozen garments, dozen pairs, etc.; but to use trade units intelligently requires a knowledge of the pounds or yards in each such unit, so for common use it is best to give the production in common units.

Pound is the Simplest Unit. — The pound is the simplest unit since it is the easiest to measure and since the length and breadth of the fabric do not have to be considered.

Production Factors. — The production in pounds depends on the following variables: needle velocity, number of feeds, weight of yarn, length of stitch and actual running time — five in all.

Explanation of Diametral Revolutions. — Needle velocity is generally expressed as revolutions per minute, to which it is proportional for a given diameter, i.e. if one 20-inch machine runs 20 r.p.m. and another 40 r.p.m., the needle velocity of the second cylinder is twice that of the first. But this method of expressing the velocity necessitates stating the diameter in every case, so it is better to express the velocity in diametral revolutions per minute (dia. r.p.m.) which is the product of the diameter in inches and the revolutions per minute. A 20-inch machine running 20 r.p.m. has a needle velocity of $20 \times 20 = 400$ dia. r.p.m. This is especially convenient for knitting machines, in which the needle velocity is generally constant for different diameters, since it not only facilitates calculating the production but enables determining the speed of different-sized machines.

Diametral-revolutions Constant for Knitting Machine. — Suppose a particular kind of work is tried on a 20-inch machine and is found to run best at 20 r.p.m. Then 20×20 or 400 is the speed in dia. r.p.m. for all of the machines; according to which a 10-inch should run $400 \div 10 = 40$ r.p.m., and a 16-inch, $400 \div 16 = 25$ r.p.m. For these and other reasons the needle velocity is expressed in dia. r.p.m. and 700 is taken as a fair average for rib work, except automatic work on small machines for which 420 is taken.

Conditions for High Velocity. — Generally, good conditions of yarn, machine and attendance favor good needle velocity and vice versa. Light yarn and a fairly loose stitch favor good velocity, since bunches and knots have room to pass between the needles without causing trouble. Each manufacturer should determine for himself the best speed for his conditions.

Advisable to Start Low. — It is advisable to start low and then gradually work up to the point where the cost of knitting per unit of production is the least.

Maximum Number of Feeds Generally Used. — The number of feeds is generally the greatest that can be used on the machine or for the pattern required.

Selection of Yarn Number. — The weight of yarn is limited to an extent by the cut and after that by the weight of the goods, the cost of the goods, etc. Since cotton is the most used knitting material, the number of the yarn is generally given in the cotton count.

Number of Yarn Proportional to Square of Cut. — The number of the yarn is proportional to the square of the cut or gauge, i.e. if the cut is made twice as fine, the yarn number should be four times as fine.

Possible Variation of Yarn. For latch-needle rib machines the variation in the yarn number for a given cut is generally not over twice the heaviest. In other words, if No. 8 is about as heavy as is practical, No. 16 would be about the light limit. It is of course understood that the extreme light limit is the lightest thread that will hold together during the formation of the stitch, but the fabric so made would be worthless.

Production. Methods of Calculating

20-inch Rib Machine, 8 Feeds, 10 Cut, 624 Needles in Cylinder and 624 Needles in Dial, 16 Yarn, 4-inches of Cylinder Needles to one Foot of Yarn, 9 Hours (540 min.).

The calculations for loop-wheel machines are the same, except that 4.7 inches of cylinder needles are used instead of 4 inches for the pounds production and hanks production.

Linear Yards

$$\frac{\text{Courses per day}}{\text{Courses per yard}} .$$

$$\frac{\text{Feeds} \times \text{r.p.m.} \times \text{Minutes}}{\text{Courses per inch} \times \text{Inches per yard}}$$

$$\frac{8 \times 35 \times 540}{\text{Courses per inch} \times 36} = \frac{4200}{\text{Courses per inch}} .$$

Count the courses per inch of the sample in question or take the calculated courses from the table on page 40.

Square Yards

$$\frac{\text{Face stitches per day}}{\text{Face stitches per yard}}$$

$$\frac{\text{Feeds} \times \text{Cyl. needles} \times \text{r.p.m.} \times \text{Minutes}}{\text{Face stitches per sq. in.} \times \text{Inches in sq. yd.}}$$

$$\frac{8 \times 624 \times 35 \times 540}{\text{Face stitches per sq. in.} \times 1296} = \frac{72800}{\text{Face stitches per sq. in.}} .$$

Take the product of the wales and courses per inch of the sample in question, or take the calculated stitches per square inch from the table on page 79.

Hanks

$$\frac{\text{Feet of yarn consumed per day}}{\text{Feet in hank}}$$

$$\frac{\text{Dia. in Feet} \times 3.1416 \times \text{r.p.m.} \times \text{Feeds} \times \text{Feet of yarn in one foot of needles} \times \text{Minutes}}{\text{Feet in hank}}$$

$$\frac{\frac{20}{12} \times 3.1416 \times 35 \times 8 \times \frac{12}{4} \times 540}{2520} =$$

942.4.

Pounds

$$\frac{\text{Feet of yarn consumed per day}}{\text{Feet in pound}}$$

$$\frac{\text{Dia. in feet} \times 3.1416 \times \text{r.p.m.} \times \text{Feeds} \times \text{Feet of yarn in one foot of needles} \times \text{Minutes}}{\text{Feet in hank} \times \text{Number of yarn}}$$

$$\frac{\frac{20}{12} \times 3.1416 \times 35 \times 8 \times \frac{12}{4} \times 540}{2520 \times 16} =$$

58.90.

Stitches per Foot of Yarn and Courses per Inch. — *The length of stitch* is best expressed by the number of cylinder needles per one foot of yarn. The number of courses per inch is frequently used, but the production in pounds cannot be calculated from the courses because it is not known how much yarn is required to make a given number of courses. One foot of yarn takes up from 3 inches to 5 inches of needles in a latch-needle rib machine. For cuts from Nos. 4 to 14 inclusive and yarn $= \frac{\text{Cut}^2}{6}$, one foot of yarn fills about 4 inches of needles for a good fabric, so 4 inches is taken as the average. When the yarn is lightened, the stitch is generally tightened and vice versa.

Causes of Lost Time. — The running time of course depends on the number of hours in the working day, on the conditions of yarn, attendance, and machine, whether stop motions are used, etc. Generally, the greater the number of feeds, the greater will be the stoppage from yarn defects and for replacement of bobbins or cones. Estimates of stoppage run from 10 per cent to 20 per cent.

Factors of Linear Yard Production. — The production in linear yards is dependent on the speed, feeds, and courses per inch. It is obtained by calculating the number of courses made per day by the machine and then dividing this number by the number of courses in a yard of the fabric.

The production in hanks is found by calculating the number of yards of yarn used by the machine per day, dividing it by the number of yards in a hank, and dividing the result by the number of the yarn.

The production in square yards is equal to the number of stitches made per unit of time divided by the number of stitches per square yard; but since the latter is inconvenient to get, the stitches per square inch are used and multiplied by $36 \times 36 = 1296$, the number of square inches in a square yard.

Explanation of General Rib-fabric Production Table in Pounds

Page 72

This table gives the production in pounds for 10 hours actual running time for all factors variable except stitches, which are taken at $9.8 \sqrt{\text{No.}}$, that is, one foot of yarn occupies four inches of needles.

To use the table multiply together the diameter of the cylinder in inches, the revolutions per minute and the feeds: select the number at the top of the table nearest to this product and read the answer under it opposite the number of the yarn used.

Example. — How many pounds of fabric will be produced in ten hours under the following conditions?

Diameter of cylinder 16 inches,
Revolutions per minute 44,
Feeds 8,
Yarn No. 11 cotton,
Multiply together the diameter, the revolutions per minute, and the feeds

$$16 \times 44 \times 8 = 5{,}632.$$

See the table on page 72

The nearest number at the top of the table is 5,400, and under it, opposite No. 11 yarn is 91.75. Discount this, say 20 per cent for lost time, which gives 73.4 pounds.

The average production of spring-needle circular loop-wheel flat work is 1.23 times that given in the table. For instance, such a machine under the above conditions would, in 10 hours actual time, produce $91.75 \times 1.23 = 113$ pounds.

Production Table in Hanks for Rib Machine — Example

Page 73

How many pounds of fabric will be produced in a 10-hour day by a 6-feed, 18-inch machine running 50 r.p.m. and using No. 10 cotton yarn. The diametral revolutions are $18 \times 50 = 900$. The constant for 900 dia. r.p.m. and 6 feeds is 908.75, which divided by 10, the yarn number, = 91, the pounds production for 9 hours, which under good conditions may be taken as the production for a 10-hour day.

If the yarn is two thread get either (1) the production for the equivalent single-thread or (2) the total of the productions for each thread. For instance, what is the pounds production per 10-hour day of a 4-feed machine making 700 diametral revolutions per minute and using a No. 8 yarn and a No. 24 yarn at each feed.

(1) The equivalent single yarn is $\frac{24 \times 8}{24 + 8} = \frac{192}{32} = 6$. The constant for 700 diametral r.p.m. and 4 feeds is 471.2, which divided by $6 = 78.6$, the pounds production.

(2) The production for each thread is

$$471.2 \div 8 = 59$$
$$471.2 \div 24 = 19.6$$
$$78.6. \quad \text{Total production.}$$

General Rib-fabric Production Table in Pounds

For explanation see pages 70 and 71

Production. Pounds of rib fabric per 10 hours actual running time

Yarn No.	Diameter × r.p.m. × Feeds										
	500	1200	1900	2600	3300	4000	4700	5400	6100	6800	7500
5	18.69	44.86	71.03	97.2	123.35	149.52	175.7	201.85	228.00	254.20	280.35
6	15.58	37.38	59.19	81.00	102.80	124.60	146.4	168.22	190.00	211.80	233.65
7	13.35	32.05	50.74	69.43	88.12	106.80	125.5	144.20	162.90	181.60	200.30
8	11.68	28.04	44.39	60.75	77.10	93.46	109.8	126.16	142.52	158.87	175.23
9	10.32	24.76	39.20	53.64	68.08	82.52	96.97	111.40	125.95	140.30	154.73
10	9.35	22.43	35.52	48.60	61.68	74.76	87.85	100.94	114.00	127.10	140.19
11	8.50	20.39	32.29	44.18	56.07	67.97	79.86	91.75	103.65	115.54	127.43
12	7.79	18.69	29.60	40.50	51.40	62.30	73.21	84.11	95.02	105.90	116.80
13	7.19	17.25	27.32	37.38	47.45	57.51	67.58	77.64	87.70	97.77	107.95
14	6.68	16.02	25.37	34.72	44.06	53.40	62.75	72.10	81.44	90.78	100.13
15	6.23	14.95	23.68	32.40	41.12	49.84	58.57	67.29	76.01	84.73	93.46
16	5.84	14.02	22.20	30.38	38.55	46.73	54.91	63.08	71.26	79.44	87.85
17	5.50	13.20	20.89	28.59	36.28	43.98	51.68	59.37	67.07	74.76	82.46
18	5.19	12.46	19.73	27.00	34.27	41.54	48.81	56.07	63.34	70.61	77.89
19	4.92	11.80	18.69	25.58	32.47	39.35	46.24	53.12	60 00	66.90	73.78
20	4.67	11.21	17.75	24.30	30.84	37.38	43.92	50.46	57.00	63.55	70.09
21	4.45	10.68	16.91	23.14	29.37	35.60	41.83	48.06	54.29	60.52	66.75
22	4.25	10.20	16.14	22.09	28.04	33.98	39.93	45.88	51.82	57.77	63.72

Yarn No.	8200	8900	9600	10,300	11,000	11,700	12,400	13,100	13,800	14,500
5	306.50	332.70	358.90	385.00	411.20	437.40	463.50	489.70	515.90	542.10
6	255.45	277.25	299.05	320.85	342.70	364.50	386.30	408.10	429.90	451.70
7	219.00	237.65	256.35	275.05	293.75	312.45	331.15	349.85	368.55	387.20
8	191.60	207.95	224.30	240.65	257.00	273.40	289.70	306.10	322.40	338.80
9	169.16	183.60	198.05	212.50	226.95	241.40	255.85	270.27	284.70	299.15
10	153.26	166.35	179.43	192.51	205.60	218.70	231.80	244.85	257.95	271.05
11	139.33	151.22	163.12	175.00	186.90	198.80	210.70	222.60	234.50	246.40
12	127.70	138.60	149.50	160.40	171.35	182.50	193.15	204.05	215.00	225.95
13	117.90	127.95	138.00	186.90	158.15	168.23	178.30	188.35	198.40	208.50
14	109.47	118.80	128.15	137.50	146.85	156.20	165.55	174.90	184.25	193.60
15	102.17	110.90	119.60	128.34	137.07	145.80	154.52	163.25	171.96	180.70
16	95.80	103.97	112.15	120.32	128.50	136.70	144.86	153.04	161.22	169.40
17	90.16	97.86	105.55	113.24	120.95	128.64	136.34	144.04	151.73	159.43
18	85.16	92.42	99.70	106.95	114.23	121.50	128.77	136.05	143.30	150.58
19	80.67	87.56	94.44	101.33	108.22	115.10	122.00	128.87	135.76	142.65
20	76.63	83.17	89.71	96.25	102.80	109.34	115.88	122.42	128.96	136.50
21	72.98	79.21	85.44	91.67	97.91	104.13	110.36	115.80	116.40	129.05
22	69.66	75.62	81.56	87.51	93.46	99.41	105.35	111.30	117.25	123.20

Production Table in Hanks for Rib Machine

For example see bottom of page 71

Constants which dividedby the cotton number of the yarn give the production of latch-needle circular rib knitting machines in pounds per 9 hours actual time. The stitches per foot of yarn are four times the cut.

R.p.m. (20 in.)	Dia. r.p.m.	Feeds			
		1	2	3	4
20	400	67.31	134.63	201.95	269.27
25	500	84.14	168.30	252.43	336.60
30	600	100.97	201.95	302.93	403.90
35	700	117.80	235.61	353.42	471.20
40	800	134.63	269.27	403.90	538.53
45	900	151.46	302.92	454.38	605.85
50	1000	168.29	336.59	504.88	673.17
		5	6	7	8
20	400	336.60	403.90	471.20	538.55
25	500	420.73	504.90	589.00	673.20
30	600	504.90	605.85	706.80	807.80
35	700	589.00	706.80	824.65	942.40
40	800	673.15	807.80	942.40	1077.00
45	900	757.30	908.75	1060.20	1211.60
50	1000	841.45	1009.70	1178.00	1346.30
		9	10	11	12
20	400	605.90	673.15	740.50	807.80
25	500	757.30	841.45	925.60	1009.70
30	600	908.77	1009.70	1110.70	1211.70
35	700	1060.20	1178.00	1296.00	1413.60
40	800	1211.60	1346.30	1481.00	1615.60
45	900	1363.10	1514.60	1666.00	1817.50
50	1000	1514.50	1682.90	1851.20	2019.50
		13	14	15	16
20	400	875.20	942.50	1009.70	1077.00
25	500	1094.00	1178.00	1262.00	1346.30
30	600	1312.70	1413.70	1514.60	1615.60
35	700	1531.40	1649.30	1767.00	1885.00
40	800	1750.30	1885.00	2019.50	2154.00
45	900	1969.00	2120.50	2272.00	2423.40
50	1000	2187.90	2356.10	2524.30	2692.70

Cut	Yarn	Cut	Yarn
3	1.5	9	13.5
4	2.7	10	16.7
5	4.2	11	20.2
6	6.0	12	24.0
7	8.2	13	28.2
8	10.8	14	32.7

Production Table in Hanks for Loop-wheel Machine

Constants which divided by the cotton number of the yarn give the production of spring-needle circular loop-wheel knitting machines in pounds per ten hours actual time. The stitches per foot are three times the gauge.

R.p.m. (20 in. cyl.)	Dia. r.p.m.	Feeds									
		1	2	3	4	5	6	7	8	9	10
70	1400	223	447	670	893	1115	1337	1560	1783	2000	2230
60	1200	193	383	575	765	965	1145	1340	1530	1720	1920
50	1000	160	320	480	640	800	960	1115	1275	1435	1600
40	800	128	256	384	510	640	766	894	1020	1148	1280
30	600	97	192	290	385	480	575	670	767	860	960
20	400	65	129	193	255	325	385	450	510	575	640
10	200	32	64	95	128	160	194	224	255	290	320

Example. — What is the production in pounds per day of a 6-feed spring-needle circular loop-wheel machine 15 inches in diameter, running 60 revolutions per minute and knitting No. 10 cotton yarn?

The diametral revolutions per minute are $15 \times 60 = 900$. The table does not give this, but does give 800 and 1,000, and since what is desired is halfway between these, take half of the hanks given under 6 feeds and opposite 800 and 1,000. That is, half of $960 + 766 = \frac{1}{2} \times 1726 = 863$. This number of hanks, 863, divided by the yarn, No. 10, gives 86.3, the pounds production for 10 hours actual running time. Discount this by the proportion of lost time, or by one-tenth, if the lost time is not known. The actual production then for good conditions is $86.3 \times 0.9 = 77.7$.

For two-thread work see two-thread example for rib-production table in hanks, bottom of page 71 and top of page 72.

For fleeced-underwear fabric obtain the face production by either two-thread method, pages 71 and 72, and double it to allow for the weight of the backing.

Production Table Linear Yards — Explanation

Pages 76 and 77

If the number of courses of fabric made in an hour is known and this number is divided by the courses per yard, the quotient will be the linear yards produced per hour. Since the number of courses per inch depends both on the diameter of the yarn and on the stitches per foot of yarn, as well as on other conditions, a table to meet all of the requirements would be both bulky and costly. However, the courses produced by the machine may be easily calculated, and if the courses per inch are counted in the sample in question, if at hand, or taken from the guide table herewith, and divided into the courses produced by the machine, the linear yards may be obtained satisfactorily from a comparatively small table, such as the one on page 76.

The table is based on the following calculations:

$$\text{The courses per hour} = \text{r.p.m.} \times \text{feeds} \times 60 \quad . \quad (1).$$

$$\text{The courses per linear yard} = \text{courses per inch} \times 36 \; . \quad (2).$$

$$\text{The linear yards per hour} = (1) \div (2)$$

$$= \frac{\text{r.p.m.} \times \text{feeds} \times 60}{36 \times \text{courses per inch}}$$

$$= \frac{1.667 \times \text{r.p.m.} \times \text{feeds}}{\text{courses per inch}}$$

$$= \frac{\text{constant}}{\text{courses per inch}} .$$

The table shows the constants for different revolutions per minute of circular machines or strokes per minute of straight machines and for different numbers of feeds. The constants must be divided by the courses per inch to get the linear yards. Since the production in linear yards is independent of the diameter of the machine, except as it affects the revolutions per minute, the diameters are given merely as an alternative guide for use for latch-needle machines when the revolutions per minute are not known. Deduction should be made from the result obtained, in proportion to the time lost.

Production, Linear Yards

Pages 76 and 77

Example. — How many linear yards, per 10-hour day, of fabric having 24 courses per inch, will be produced by a 4-feed machine running 100 r.p.m.? In the table opposite 100 r.p.m. and under 4 feeds is the constant 667, which divided by 24, the number of courses, gives 27.8, the linear yards per hour, actual time. Since the machine has only four feeds, the lost time may be considered 10 per cent in the absence of definite information. Then the day will consist of 9 hours actual running time, so the actual production in linear yards per day will be $27.8 \times 9 = 250$.

Production, Linear Yards

For explanation see bottom of page 74

Constants which divided by the number of courses per inch give the production of knitting machines in linear yards **per hour.**

Dia.	R.p.m. of circular machine. Strokes per min. of straight machine	Feeds						
		1	2	3	4	5	6	7
1	700	1167.0	2333.0					
1¼	564	940.0	1880.0					
1½	462	770.0	1540.0	2310.				
1¾	400	666.7	1333.0	2000.				
2	350	583.3	1167.0	1750.				
2¼	311	518.3	1037.0	1555.				
2½	280	466.7	933.3	1400.				
2¾	255	425.0	850.1	1275.				
3	233	388.3	776.7	1165.				
3¼	215	358.3	716.7	1075.				
3½	200	333.3	666.7	1000.	1333.			
3¾	187	311.7	623.4	935.	1247.			
4	175	291.7	583.3	875.	1167.			
4¼	165	275.0	550.0	825.	1100.	1375.		
4½	156	260.0	520.0	780.	1040.	1300.		
4¾	147	245.0	490.0	735.	980.	1225.		
5	140	233.3	466.7	700.	933.	1167.		
5¼	133	221.6	443.3	665.	887.	1108.	1333.	1552.
5½	127	211.7	423.3	635.	847.	1058.	1270.	1482.
5¾	122	203.3	406.7	610.	813.	1017.	1220.	1423.
6	117	195.0	390.0	585.	780.	975.	1170.	1365.
7	100	166.7	333.3	500.	667.	833.	1000.	1167.
8	88	146.7	293.3	440.	587.	733.	880.	1027.
9	78	130 0	260.0	390.	520.	650.	780.	910.
10	70	116.7	233.3	350.	467.	583.	700.	817.
11	64	106.7	213.3	320.	427.	533.	640.	747.
12	58	96.7	193.3	290.	387	483.	619.	677.
13	54	90.0	180.0	270.	360.	450.	540.	630.
14	50	83.3	166.7	250.	333.	417.	500.	583.
15	47	78.3	156.7	235.	313.	392.	470.	548.
16	44	73.3	146.7	220.	293.	367.	440.	513.
17	41	68.3	136.7	205.	273.	342.	410.	478.
18	39	65.0	130.0	195.	260.	325.	390.	455.
19	37	61.7	123.3	185.	247.	308.	370.	431.
20	35	58.3	116.7	175.	233.	292.	351.	408.
21	33	55.0	110 0	165.	220.	275.	330.	385.
22	32	53.3	106.7	160.	213.	267.	320.	373.
23	30	50.0	100.0	150.	200.	250.	300.	350.
24	29	48.3	96.7	145.	193.	242.	290.	338.

If the number of courses is not known, but the cut is known, then from the guide table take the number of courses opposite the cut.

Excepting the diameter column and the cut table the figures apply to any knitting machine, either circular or straight.

Dia.	R.p.m. of circular machine. Strokes per min. of straight machine	Feeds								
		8	9	10	11	12	13	14	15	16
1	700									
1¼	564									
1½	462									
1¾	400								Guide table	
2	350								Cut	Courses
2¼	311								6	16
2½	280								7	19
2¾	255								8	21
3	233								9	24
3¼	215								10	27
3½	200								11	29
3¾	187								12	32
4	175								13	35
4¼	165								14	38
4½	156									
4¾	147									
5	140									
5¼	133									
5½	127									
5¾	122									
6	117	1560.								
7	100	1333.	1500.							
8	88	1173.	1320.	1467.						
9	78	1040.	1170.	1300.	1430.					
10	70	933.	1050.	1167.	1283.	1400.				
11	64	853.	960.	1067.	1173.	1280.	1387.			
12	58	773.	870.	967.	1063.	1160.	1257.	1353.		
13	54	720.	810.	900.	990.	1080.	1170.	1260.	1350.	
14	50	667.	750.	833.	917.	1000.	1083.	1167.	1250.	1330.
15	47	627.	705.	783.	862.	940.	1018.	1097.	1175.	1253.
16	44	587.	660.	733.	807.	880.	953.	1027.	1100.	1173.
17	41	547.	615.	683.	752.	820.	888.	957.	1025.	1093.
18	39	520.	585.	650.	715.	780.	845.	910.	975.	1040.
19	37	493.	555.	616.	678.	740.	802.	863.	925.	987.
20	35	467.	525.	583.	642.	700.	758.	817.	875.	933.
21	33	440.	495.	550.	605.	660.	715.	770.	825.	880.
22	32	427.	480.	533.	587.	640.	693.	747.	800.	853.
23	30	400.	450.	500.	550.	600.	650.	700.	750.	800.
24	29	387.	435.	483.	532.	580.	628.	677.	725.	773.

Square-yard Production Table, Page 79 — Derivation

This table is intended to be used when the wales and courses are known, such as is the case when the question arises, how many square yards of a given fabric may be produced per hour. The wales per inch and courses per inch of the fabric may be counted and multiplied together in order to get the stitches per square inch, which divided into the figures given in the table gives the square yards per hour. The approximate cut may be determined by the guide column of calculated stitches per square inch. The table is the result of the following calculation.

$$\begin{aligned}
\text{Sq. Yds. per hr.} &= \text{Face stitches per hour} && \div \text{ Face stitches per sq. yd.} \\
&= \text{Feeds} \times \text{cyl. needles} \times \text{r.p.m.} \times 60 && \div\ 1296 \text{ Face stitches per sq. in.} \\
&= \text{Feeds} \times \text{cut} \times 3.1416 \times \text{Dia.} \times \text{r.p.m.} \times 60 && \div\ 1296 \text{ Face stitches per sq. in.} \\
&= \text{Feeds} \times \text{cut} \times \frac{3.1416 \times 700 \times 60}{1296} && \div \text{ Face stitches per sq.in.} \\
&= \text{Feeds} \times \text{cut} \times 101.811 && \div \text{ Face stitches per sq. in.}
\end{aligned}$$

Attention is called to the fact that machines are not always made with the exact number of needles called for by the cut and the diameter, so some slight discrepancy may be observed between the yards given by this table and the yards calculated from the exact number of needles used or obtained in practice. The cut is generally known or ascertained more readily than the number of needles, so it is used in the table. If the needles are used, the diameter must also be used, and then the revolutions per minute as well, whereas by using the cut instead of the needles, the diameter and revolutions per minute are both displaced by 700, their constant product. If the yards for different diametral revolutions are desired, they are obtainable by simple proportion.

Suppose the diameter is 10 inches and the r.p.m. 80. Then the diametral revolutions are 800, so the yards obtained by use of the table should be multiplied by $\frac{800}{700}$ to get the yards for the required conditions.

Production Table, Square Yards, for Use when the Wales and the Courses are Known

For example see top of page 80

Constants which divided by the stitches per square inch give the production in yards **per hour** for a needle velocity of 700 diametral revolutions per minute. Deduction should be made for whatever time is lost. Applicable to all circular machines except the column of "approximate stitches per square inch," which is for rib machines only.

Cut	Approximate stitches per sq. in.	Feeds															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
3	52	305.433	611	916	1222	1527	1833	2,138	2,444	2,749	3,054	3,360	3,665	3,971	4,276	4,582	4,887
4	92	407.244	815	1222	1629	2036	2443	2,851	3,258	3,665	4,072	4,480	4,887	5,294	5,702	6,109	6,516
5	144	509.055	1018	1527	2036	2545	3054	3,563	4,072	4,581	5,091	5,600	6,109	6,618	7,127	7,636	8,145
6	207	610.866	1222	1833	2443	3054	3665	4,276	4,887	5,498	6,109	6,720	7,330	7,941	8,553	9,163	9,754
7	281	712.677	1425	2138	2851	3563	4276	4,988	5,701	6,414	7,126	7,840	8,552	9,265	9,978	10,690	11,400
8	367	814.488	1629	2443	3258	4072	4887	5,701	6,516	7,330	8,145	8,960	9,774	10,590	11,400	12,220	13,030
9	465	916.299	1833	2749	3665	4582	5498	6,414	7,333	8,246	9,163	10,080	11,000	11,910	12,830	13,740	14,660
10	574	1018.110	2036	3054	4072	5091	6109	7,127	8,145	9,163	10,180	11,200	12,220	13,240	14,250	15,270	16,290
11	752	1119.920	2240	3360	4480	5600	6720	7,840	8,960	10,080	11,200	12,320	13,440	14,560	15,680	16,800	17,920
12	827	1221.730	2443	3665	4887	6109	7331	8,553	9,774	11,000	12,220	13,440	14,660	15,880	17,110	18,330	19,550
13	970	1323.540	2647	3971	5294	6618	7942	9,265	10,590	11,910	13,240	14,560	15,880	17,210	18,530	19,850	21,180
14	1125	1425.356	2851	4276	5702	7127	8552	9,978	11,400	12,830	14,250	15,680	17,110	18,530	19,960	21,380	22,820
15	1292	1527.160	3054	4582	6109	7636	9163	10,690	12,220	13,740	15,270	16,800	18,330	19,850	21,380	22,910	24,440
16	1470	1628.976	3258	4887	6516	8145	9774	11,400	13,030	14,660	16,290	17,920	19,555	21,180	22,800	24,440	26,060

Example. — How many square yards per hour will be produced by an 8 cut machine with 10 feeds making fabric with 17 wales and 22 courses per inch? The stitches per square inch are $17 \times 22 = 374$. The constant in the table on page 79 at the intersection of 8 cut and 10 feeds is 8145, which divided by 374 = 21.8, the square yards per hour, no lost time.

Explanation of Square Yard Table for Use when the Number of Cylinder Needles, Revolutions per Minute and Feeds are Known, Page 81

This table is designed to give in compact form the production in square yards for varying conditions of speed, feeds, needles, and yarn. The only condition which is fixed is the stitch which is taken at $9.8\sqrt{\text{No.}}$ per one foot of yarn for rib fabric and $19.6\sqrt{\text{No.}}$ for flat fabric.

To use the table, multiply together the number of needles in the cylinder, the revolutions per minute, and the feeds. Select the number at the top nearest to this product and run down the column until opposite the yarn used, where will be found the square yards for 10 hours' actual running time. Discount this for the lost time, say 20 per cent for a rib body machine and 10 per cent for a ribber or flat-work machine if the lost time is not known.

Example. — How many square yards will be produced in ten hours under the following conditions?

Needles in cylinder, 400 (8 cut, 16 inches).
Revolutions per minute, 44.
Feeds, 8.
Yarn, No. 11 cotton.
(The stitch used is 32.5 for rib fabric or 65 for flat fabric.)
Multiply together,
The needles, the revolutions per minute, and the feeds;

$$400 \times 44 \times 8 = 140{,}800.$$

The nearest number to this at the top of the table is 150,000, under which, opposite No. 11 yarn is 183.3. If a closer result is desired, multiply 183.3 by $\frac{1408}{1500}$ which gives 172. Discount 20 per cent for lost time, which gives 137.5 square yards.

Production, Square Yards of Regular Cotton Single Thread Fabric

For example see bottom of page 80

For 10 hours actual running time when the number of cylinder needles, revolutions per minute, and feeds are known.

Yarn No.	Cylinder needles × r.p.m. × feeds										
	10000	30000	50000	70000	90000	110000	130000	150000	170000	190000	210000
5	26.87	80.62	134.40	188.10	241.90	295.60	349.40	403.10	456.9	510.6	564.4
6	22.40	67.19	112.00	156.80	201.50	246.40	291.20	336.00	380.8	425.5	470.3
7	19.20	57.59	95.99	134.40	172.80	211.20	249.60	288.00	326.4	364.8	403.2
8	16.80	50.40	83.99	117.60	151.20	184.80	218.40	252.00	285.6	319.2	352.8
9	14.93	44.79	74.65	104.50	134.40	164.20	194.10	224.00	253.8	283.7	313.5
10	13.44	40.31	67.19	94.06	120.90	147.80	174.70	201.60	228.4	255.3	282.2
11	12.22	36.65	61.08	85.52	109.90	134.40	158.80	183.30	207.7	232.1	256.5
12	11.20	33.59	55.98	78.38	100.80	123.20	145.60	168.00	190.4	212.7	235.1
13	10.34	31.01	51.68	72.36	93.02	113.70	134.40	155.00	175.7	196.4	217.1
14	9.598	28.79	47.99	67.18	86.38	105.60	124.80	144.00	163.2	182.4	201.6
15	8.958	26.87	44.79	62.70	80.62	98.54	116.40	134.40	152.3	170.2	188.1
16	8.398	25.20	41.99	58.79	75.59	92.39	109.20	126.00	142.8	159.6	176.4
17	7.905	23.71	39.52	55.33	71.14	86.96	102.80	118.60	134.4	150.2	166.0
18	7.465	22.40	37.33	52.26	67.18	82.12	97.06	112.00	126.9	141.8	156.8
19	7.072	21.22	35.36	49.50	63.64	77.80	91.94	106.10	120.2	134.4	148.5
20	6.719	20.16	33.59	47.03	60.46	73.90	87.34	100.80	114.2	127.7	141.1
21	6.398	19.20	31.99	44.79	57.58	70.38	83.18	95.98	108.8	121.6	134.4
22	6.108	18.32	30.54	42.76	54.97	67.19	79.41	91.63	103.8	116.0	128.3

Yarn No.	Cylinder needles × r.p.m. × feeds									
	230000	250000	270000	290000	310000	330000	350000	370000	390000	410000
5	618.1	671.9	725.6	779.4	833.1	886.8	940.6	994.4	1048.0	1102.0
6	515.1	555.9	604.7	649.5	694.3	739.1	783.9	828.7	873.4	918.2
7	441.5	480.0	518.3	556.7	595.1	633.5	672.0	710.3	748.7	787.1
8	386.4	420.0	453.6	487.2	520.7	554.3	587.9	621.6	655.1	688.7
9	343.4	373.2	403.1	433.0	462.8	492.7	522.5	552.4	582.2	612.1
10	309.1	335.9	362.8	389.7	416.5	443.4	470.3	497.2	524.0	550.9
11	281.0	305.4	329.8	354.3	378.7	403.1	427.6	452.0	476.4	500.8
12	257.5	279.9	302.3	324.7	347.1	369.5	391.9	414.3	436.7	459.0
13	237.7	258.4	279.1	299.8	320.4	341.1	361.8	382.4	403.1	423.8
14	220.8	240.0	259.1	278.3	297.5	316.7	335.9	355.1	374.3	393.5
15	206.0	223.9	241.9	259.8	277.7	295.6	313.5	331.4	349.4	367.2
16	193.2	210.0	226.8	243.6	260.4	277.2	294.0	310.2	327.5	344.3
17	181.8	197.6	213.4	229.2	245.0	260.9	276.7	292.5	308.3	324.1
18	171.7	186.6	201.6	216.5	231.4	246.4	261.3	276.2	291.1	306.1
19	162.7	176.8	190.9	205.1	219.2	233.4	247.5	261.7	275.8	290.0
20	154.5	168.0	181.4	194.8	208.3	221.7	235.1	248.6	262.0	275.5
21	147.2	160.0	172.7	185.6	198.3	211.1	223.9	236.7	249.5	262.3
22	140.5	152.7	164.9	177.1	189.5	201.6	201.6	226.0	238.2	250.4

This table is based on:

Stitches per foot of yarn equal $9.8\sqrt{\text{No. of the yarn}}$ for rib fabric and $19.6\sqrt{\text{No. of the yarn}}$ for flat fabric.

Stitches per square inch of fabric equal 34.453 × No. of the yarn.

Rib-top Production Table — Explanation

This table gives the production in dozen pairs of rib tops for single-feed ribbers running 700 diametral inches per minute that is, a 3-inch running 700 ÷ 3 = 233 r.p.m. If the two-speed drive is used, deduct 4 per cent for every tenth of the time it is used. Deduction should also be made for lost time in whatever proportion of the whole time it amounts to.

To use the table count the courses per inch in the rib top in question; or if none is at hand, use the courses in the guide table. Suppose no sample is at hand, but that it is desired to

Rib-top Table

Cut	Average courses
4	11
5	13
6	16
7	19
8	21
9	24
10	27
11	29
12	32
13	35
14	38

Courses per inch	Ins.	2¾
	6	95.4
12	7	81.8
13 11	8	71.6
14 13 11	9	63.6
17 14 13 11	10	57.3
18 16 14 12 11	11	52.0
20 17 15 13 12 11	12	47.7
22 19 16 14 13 12 11	13	44.1
23 20 18 16 14 13 12 11	14	40.9
25 21 19 17 15 14 13 12 11	15	38.2
27 23 20 18 16 15 13 12 11	16	35.8
28 24 21 19 17 15 14 13 12 11	17	33.7
30 26 23 20 18 16 15 14 13 12 11	18	31.8
32 27 24 21 19 17 16 15 14 13 12 11	19	30.1
33 29 25 22 20 18 17 15 14 13 12 11	20	28.6
35 30 26 23 21 19 18 16 15 13 12 11	21	27.3
37 31 28 24 22 20 18 17 16 15 14 13 12 11	22	26.0
38 33 29 26 23 21 19 18 16 15 14 13 12 11	23	24.9
34 30 27 24 22 20 18 17 16 15 14 13 12 11	24	23.9
36 31 28 25 23 21 19 18 17 16 15 14 13 13 12 11	25	22.9
33 29 26 24 22 20 19 17 16 15 14 13 12 11	26	22.0
34 30 27 25 23 21 19 18 17 16 15 14 13 12 11	27	21.2
35 31 28 26 23 22 20 19 18 16 15 14 12 11	28	20.5
36 32 29 26 24 22 21 19 18 17 16 15 14 13 12 11	29	19.7
38 33 30 27 25 23 21 20 19 18 17 16 15 14 13 12 11	30	19.1
40 36 33 31 29 27 25 24 22 21 20 19 18 17 16 15 14 14 13		14.3
38 36 33 31 29 28 26 25 24 23 22 21 20 19 18 17		11.5
40 38 35 33 31 30 29 27 26 25 24 23 22 21 20		9.6
39 37 35 33 32 30 29 28 27 26 25 24 23		8.2
43 41 39 38 36 35 33 32 31 30		6.4
41 39 38 37		5.2

know how many dozen pairs of rib tops will be made under the following conditions:

Cut 10.
Courses (from table) 27.
Length 15 inches.
Diameter of machine $4\frac{1}{2}$.
Two-speed drive is used on low speed about $\frac{1}{5}$ time.
Lost time is estimated 10 per cent.
Desired, the production in pairs of rib tops per 9-hour day.

Rib-top Table

Diameters: One feed										
3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$
87.5	80.8	75.0	70.0	65.6	61.7	58.3	55.3	52.5	50.0	44.7
75.0	69 2	64.3	60.0	56.2	52.9	50.0	47.3	45.0	43.0	40.9
65.6	60.6	56.3	52 5	49.4	46.3	43.8	41.4	39.4	37.5	35.8
58.3	53.8	50.0	46.7	43.8	41.2	38.9	36.8	35.0	33.3	31.8
52.5	48.5	45.0	42.0	39.4	37.1	35.0	33.2	31.5	30.0	28.6
47.7	44.1	40.9	38.2	35.8	33.7	31.8	30.1	28.6	27.3	26.0
43.8	40.4	37.5	35.0	32.8	30.9	29.2	27.6	26.2	23.3	23.9
40.4	37.3	34.6	32.3	30.3	28.5	26.9	25.5	24.2	23.1	22.0
37.5	34.6	32.2	30.0	28.1	26.5	25.0	23.7	22.5	21.4	20.5
35.0	32.3	30.0	28.0	26.3	24.7	23.3	22.1	21.0	20.0	19.1
32.8	30.3	28.1	26.2	24.6	23.2	21.9	20.7	19.7	18.8	17.9
30.9	28.5	26.5	24.7	23.2	21.8	20.6	19.5	18.5	17.6	16.8
29.2	26.9	25.0	23.3	21.9	20.6	19.4	18.4	17.5	16.7	15.9
27.6	25.5	23.7	22.1	20.7	19.5	18.4	17.4	16.6	15.8	15.1
26.3	24.2	22.5	21.0	19.7	18.5	17.5	16.6	15.8	15.0	14.3
23.9	23.1	21.4	20.0	18.8	17.6	16.7	15.8	15.0	14.3	13.6
23.8	22.0	20.5	19.1	17.9	16.8	15.9	15.1	14.3	13.6	13.0
22.8	20.6	19.6	18.3	17.1	16.1	15.2	14.4	13.7	13.0	12.5
21.9	20.2	18.8	17.5	16.4	15.4	14.6	13.8	13.1	12.5	11.9
21.0	19.4	18.0	16.8	15.8	14.8	14.0	13.3	12.6	12.0	11.5
20.2	18.6	17.3	16.2	15.1	14.3	13.5	12.8	12.1	11.5	11.0
19.4	17.9	16.7	15.6	14.6	13.7	13.0	12.3	11.7	11.1	10.6
18.8	17.3	16.1	15.0	14.1	13.2	12.5	11.8	11.3	10.7	10 2
18.1	16.7	15.5	14.5	13.6	12.8	12.1	11.4	10.9	10.3	9.9
17.5	16.2	15.0	14.0	13.1	12.4	11.7	11.1	10.5	10.0	9.5
13.1	12.1	11.2	10.5	9.8	9.3	8.8	8.3	7.9	7.5	7.2
10.5	9.7	9.0	8.4	7.9	7.4	7.0	6.6	5.5	6.0	5.7
8.8	8.1	7.5	7.0	6.6	6.2	5.8	5.5	5.2	5.0	4.8
7.5	6.9	6.4	6.0	5.6	5.3	5.0	4.7	4.5	4.3	4.1
5.6	5.4	5.0	4.7	4.4	4.1	3.9	3.7	3.5	3.3	3.2
4.8	4.4	4.1	3.8	3.6	3 4	3.2	3.0	2.9	2.7	2.6

Dozen pairs per 9 hours actual time.

Follow down the column marked inches to 15, the length of the top; then down the diagonal column to the left to 27, the number of courses; then horizontally to the right to the column headed $4\frac{1}{2}$, the diameter of the ribber, where is 8.8 the number of dozen pairs of rib tops. Deduct 8 per cent for two-speed drive, which is 0.35, leaving 8.45, and then deduct 10 per cent for lost time, which is 0.85, leaving 8 dozen pairs, in round numbers, which is the production for a nine-hour day.

RELATIVE PRODUCTION OF DIFFERENT TYPES OF KNITTING MACHINES

The importance of the fabric formulas is illustrated by the light which they throw on the relative production of different kinds of knitting machines.

The formulas show not only the actual corresponding production for the conditions assumed, but also the principles by which comparison may be made for any other conditions.

Results according to the formulas will be considered first, and the general considerations will be given afterward.

Primarily it is best to consider the production per feed, since practice varies so much in regard to the number of feeds used with a given diameter of machine that no other unquestionable ground could be found. Of course, the relative speed, yarn and stitch have to be assumed. They are discussed quite fully in different places in this book, but are roughly summarized here to avoid confusion.

One obstacle in the way of comparisons formerly was the absence of a connecting link between any two different kinds of machine. For instance, if the same number of needles per inch was considered, there was a question about the fairness of such a basis due to the fact that different yarn was used on the different machines for the same number of needles per inch, and since the relative size of the yarn was not known, the question was unanswerable. The length of the stitch had but little attention. But the yarn-cut rules and stitch rules provide the missing links, so that comparison may be made on the basis of either the same cut or of the same yarn, both of which comparisons are necessary for a comprehensive understanding of the subject.

The table gives: (1) the formulas just as they appear in the tabulations of formulas for regular fabrics; (2) the actual production per feed per ten hours for 12 cut and 24 yarn, a suitable

Relative Production of Latch-needle Rib Machine and Spring-needle Loop-wheel Machine Under Following Relative Conditions

	Relative yarn No. for same cut	R.p.m. of 20 in. cyl.	Cyl. stitches per foot of yarn
Latch-needle rib	3 (about)	35	1
Spring-needle loop-wheel	1	50	1.16

Comparison. One Rib Feed to One Flat Feed

		Rule			Actual		Proportion	
		Rib	Flat		Rib	Flat	Rib	Flat
Pounds production	Same yarn	$\frac{131}{No.}$	$\frac{161}{No.}$	24 yarn	5.46	6.71	1	1.23
	Same cut	$\frac{786}{Cut^2}$	$\frac{2867}{Cut^2}$	12 cut (18 gauge)	5.46	19.9	1	3.65
Square yards production	Same yarn	$\frac{72.39}{\sqrt{No.}}$	$\frac{178}{\sqrt{No.}}$	24 yarn	14.78	36.3	1	2.46
	Same cut	$\frac{177.31}{Cut}$	$\frac{750.6}{Cut}$	12 cut (18 gauge)	14.78	62.5	1	4.23

Comparison. Two Rib Feeds to One Flat Feed

		Rule			Actual		Proportion	
		Rib	Flat		Rib	Flat	Rib	Flat
Pounds production	Same yarn	$\frac{262}{No.}$	$\frac{161}{No.}$	24 yarn	10.92	6.71	1	.62
	Same cut	$\frac{1572}{Cut^2}$	$\frac{2867}{Cut^2}$	12 cut (18 gauge)	10.92	19.9	1	1.83
Square yards production	Same yarn	$\frac{144.78}{\sqrt{No.}}$	$\frac{178}{\sqrt{No.}}$	24 yarn	29.56	36.3	1	1.23
	Same cut	$\frac{354.62}{Cut}$	$\frac{750.6}{Cut}$	12 cut (18 gauge)	29.56	62.5	1	2.12

combination for the latch-needle rib machine; and (3) the relative production, considering that of the rib machine as 1. Then all this is repeated with the production of the rib feed doubled, in order to show roughly the relative production per machine (cylinder), since in practice the number of feeds used per machine is about two to one, in favor of the rib machine.

It should be remembered that when the yarn is alike the cut of the machines is different, and when the cut is alike the yarn is different; so when 24 yarn is the basis of comparison, the rib machine is 12 cut and the loop-wheel machine 31 gauge, whereas when the cut is 12 (18 gauge), the yarn on the loop-wheel machine is No. 8 and on the rib machine 24.

Not only the actual production, but the proportional production also may be obtained from the formulas, as is illustrated by the pounds production per feed for yarn the same (24). Comparing rib to flat, the formula constants are 131 to 161, the actual pounds are 5.46 to 6.71, and the relative pounds are 1 to 1.23; these are all in the same proportion.

The comparison of production per machine shows the rib machine to lead in pounds for the same yarn as 100 to 62, but to fall behind in the yardage as 100 to 183. The loop-wheel machine leads for the same cut both in pounds and yards.

Although the comparison just made is useful when the formulas fit the conditions, it is desirable to understand the reasons why the production of one type of machine differs from another. The general principles may be shown by taking the production of one machine and modifying it according to the given conditions until it shows the production of the other machine. For simplicity the reduction will be made from the latch-needle rib machine to the loop-wheel flat-work machine.

Although the factors involved are comparatively simple, still confusion is likely to result if the production in pounds is not considered separately from the production in square yards, so the production in pounds will be considered first, under the two general cases: (1) the same yarn; (2) the same cut. Then the production in square yards will be considered in the same order.

Relative Production of Different Types of Knitting Machines per Feed

Latch-needle Rib Compared to Loop-wheel Spring-needle Flat-work Machine

Pounds, yarn the same.

Factors which Affect the Difference in Production

Rib to Flat
- Needle Velocity. Assumed 35 to 50 or 1 to 1.43
- Length of yarn fed in equal needle travel $= \frac{\text{Cut}}{\text{Stitches}}$. Formulas $\frac{2.4495\sqrt{\text{No.}}}{9.798\sqrt{\text{No.}}}$ to $\frac{4.2165\sqrt{\text{No.}}}{19.596\sqrt{\text{No.}}}$ or 1 to .86

Relative Production Calculation

(Velocity) (Length yarn)

Rib. $1 \times \frac{1.43}{1} \times \frac{0.86}{1} = 1.23$ pounds production per feed of flat to 1 of rib for yarn the same.

Pounds. Cut the Same.
Additional Factor.

Rib to Flat, Diameter of Yarn. Formulas. $\frac{1}{8.573\text{ Cut}}$ to $\frac{1}{4.98\text{ Cut}}$ or 1 to 1.72.

Relative Production Calculation

(Velocity)(Length yarn)(Dia. yarn squared)

Rib. $1 \times \frac{1.43}{1} \times \frac{0.86}{1} \times \frac{1.72}{1} \times \frac{1.72}{1} = 3.65$ pounds production per feed of flat to 1 of rib for cut the same.

The relative velocity needs no explanation, since it is clear hat if all other conditions are the same, a machine which runs aster than another will produce more fabric.

Now in this case there is one factor other than the velocity o be considered, which factor is the relative length of yarn which is drawn in by each machine for an equal needle travel. It is evident that if machines *A* and *B* are of the same cut and have the same needle velocity, but *A* is running at 30 stitches per foot of yarn and *B* at 40 stitches, then *B* has to run farther in order to use a foot of yarn, and the distance it has to run as compared to *A* is as 40 is to 30. Therefore, when each runs an equal distance, the relative lengths of yarn consumed will be as 1 ÷ 30 is to 1 ÷ 40, which is the same as 40 is to 30. Consequently, *the length of yarn consumed by two machines of the same cut and needle velocity is inversely proportional to their respective stitches per foot of yarn.*

If the machines have the same needle velocity and stitches per foot of yarn, but *A* has a finer cut, then *A* will draw the yarn in faster, since it will draw more stitches during an equal travel. And since the machines to be compared are frequently of different cut, it is desirable to have a means of comparison which will take into consideration both the stitches per foot of yarn and the cut. This means can be worked out as follows. The stitches per foot divided by the cut give the distance in inches which each machine must travel in order to draw in an equal length of yarn. Therefore, the reciprocal of this, that is, the cut divided by the stitches, gives the relative length of yarn drawn in for an equal needle travel. Consequently, *the length of yarn consumed by each of two machines of the same needle velocity but different cuts is proportional to the cut divided by the stitches per foot of yarn, respectively.*

The length-of-yarn factor used is worked out according to the last statement, which factor together with the velocity factor shows that when a latch-needle rib machine produces one pound per feed a loop-wheel flat-work machine, using the same yarn produces 1.23 pounds. This was shown before by a comparison of the results obtained with the formulas, but this method shows how it may be determined without the formulas, provided the relative cuts, stitches, and velocities are known.

When the yarn used on the two machines is different, the problem is just the same as before with the exception that the added factor of diameter of yarn squared has to be used since the machine using the heavier yarn will produce more in the proportion of the square of the diameter.

Square yards. — Yarn the same. (See Factors, page 87.)

Relative Production Calculation

(Velocity) (Width of Fabric)

Rib. $1 \times \frac{1.43}{1} \times \frac{1.72}{1} = 2.46$ square-yards production per feed of flat to 1 of rib for yarn the same.

Cut the same.

Relative Production Calculation

(Velocity) (Dia. yarn squared)

Rib. $1 \times \frac{1.43}{1} \times \frac{1.72}{1} \times \frac{1.72}{1} = 4.23$ square-yards production per feed of flat to 1 of rib for cut the same.

The following tabulation shows the method of working out the relative production in square yards.

It is noticeable at once that the length of yarn is not a factor in the square-yards production, but that the machine velocity and yarn diameter are factors. The reason for this may be understood with the aid of the following tabulation of the relative machine conditions for the two different cases.

		Dia. cyl.	Cut	Dia. yarn	Number of needles	R.p.m.	Width of fabric
Yarn same	Rib........	1	1	1	1	35	1
	Flat........	1	1.72	1	1.72	50	1.72
Cut same	Rib........	1	1	1	1	35	1
	Flat........	1	1	1.72	1	50	1.72

Evidently the diameter of the machine does not change, but since, for yarn the same, the cut does change, the number of needles must also change. Consequently, for the same yarn the machine with the more needles makes the wider fabric, and with the same number of needles the machine with the heavier yarn makes the wider fabric. This shows how it is that the yarn diameter affects the square-yards production. When the yarn is the same, the fabric is wider in proportion to the number of needles, which is proportional to the cut, which is proportional to the diameter of yarn which the machine would use with an equal cut. Therefore, the square-yards production of the machine with the finer cut is increased in proportion to the diameter of yarn which is used with an equal cut.

But when the cut is the same, the flat machine uses yarn which, according to the rule for corresponding fabrics that the dimensions of an individual stitch are proportional to the diameter of the yarn, makes the fabric both wider and longer for an equal number of stitches; consequently, the square-yards production is increased in proportion to the square of the diameter of the yarn.

WEIGHT PER SQUARE YARD FORMULA — DERIVATION

The weight in pounds of a square yard of cloth is evidently the number of stitches in a yard divided by the number of stitches in a pound. The number of stitches in a yard is:

Weight per Square Yard of Plain Ribbed Fabric Made of Single Carded Cotton Hosiery Yarn

Stitches per foot of yarn	Yarn Numbers															
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21.91	**.8087**	.6745	.5781	.5059	.4497	.4047										
24.00	.8856	**.7380**	.6326	.5535	.4920	.4428	.4025	.3690								
25.92	.9567	.7973	**.6834**	.5979	.5315	.4783	.4348	.3986	.3680	.3417						
27.71	1.0230	.8525	.7307	**.6394**	.5683	.5115	.4650	.4262	.3934	.3653	.3410	.3197				
29.39	1.0850	.9042	.7750	.6780	**.6028**	.5425	.4932	.4520	.4173	.3875	.3617	.3391	.3191	.3014		
30.98	1.1440	.9532	.8170	.7149	.6354	**.5719**	.5199	.4766	.4399	.4085	.3813	.3574	.3364	.3177	.3010	.2860
32.50	......	.9994	.8566	.7495	.6662	.5996	**.5451**	.4997	.4612	.4283	.3997	.3747	.3527	.3331	.3156	.2998
33.94	......	1.0440	.8949	.7830	.6960	.6264	.5694	**.5220**	.4818	.4474	.4176	.3915	.3685	.3480	.3297	.3132
35.32	......	......	.9312	.8148	.7243	.6518	.5925	.5432	**.5014**	.4655	.4345	.4074	.3834	.3621	.3431	.3259
36.66	......	......	.....	.8456	.7517	.6765	.6150	.5638	.5202	**.4832**	.4510	.4228	.3980	.3758	.3560	.3383
37.94	......	......	.....	.8755	.7782	.7004	.6367	.5837	.5388	.5003	**.4669**	.4378	.4120	.3891	.3686	.3502
39.19	......	......	.....	.....	.8038	.7234	.6576	.6028	.5564	.5167	.4823	**.4521**	.4255	.4019	.3807	.3617
40.34	......	......	.....	.....	.8285	.7456	.6778	.6213	.5735	.5326	.4970	.4660	**.4386**	.4142	.3924	.3728
41.57	......	......	.....	.....	.....	.7672	.6974	.6393	.5901	.5480	.5114	.4795	.4513	**.4262**	.4038	.3836
42.70	......	......	.....	.....	.....	.7881	.7164	.6568	.6062	.5629	.5254	.4926	.4636	.4378	**.4148**	.3940
43.80	......	......	.....	.....	.....	.....	.7352	.6740	.6221	.5777	.5392	.5055	.4757	.4493	.4257	**.4044**
44.90	......	......	.....	.....	.....	.....	.....	.6906	.6374	.5919	.5525	.5180	.4875	.4604	.4362	.4144
45.95	......	......	.....	.....	.....	.....	.....	.7067	.6524	.6058	.5654	.5300	.4989	.4712	.4464	.4240
46.98	......	......	.....	.....	.....	.....	.....	.....	.6670	.6194	.5781	.5420	.5101	.4818	.4564	.4336
48.00	......	......	.....	.....	.....	.....	.....	.....	.6812	.6326	.5904	.5535	.5210	.4920	.4661	.4428
48.99	......	......	.....	.....	.....	.....	.....	.....	.....	.6459	.6028	.5652	.5319	.5024	.4759	.4521
49.82	......	......	.....	.....	.....	.....	.....	.....	.....	.6585	.6146	.5762	.5424	.5122	.4853	.4610
50.91	......	......	.....	.....	.....	.....	.....	.....	.....	.....	.6258	.5868	.5522	.5216	.4941	.4694
51.84	......	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.5980	.5628	.5315	.5036	.4784
52.76	......	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.6086	.5728	.5410	.5125	.4869
53.66	......	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.5829	.5505	.5216	.4955
54.55	......	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.5923	.5594	.5299	.5034
55.42	......	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.5741	.5438	.5167
56.28	......	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.5772	.5468	.5195
57.12	......	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.5549	.5272

Weight per Square Yard of Plain Ribbed Fabric Made of Single Carded Cotton Hosiery Yarn

Stitches per foot of yarn	Yarn numbers														
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
21.91															
24.00															
25.92															
27.71															
29.39															
30.98															
32.50	.2855														
33.94	.2983	.2847	.2723												
35.32	.3104	.2963	.2834	.2716	.2607										
36.66	.3221	.3075	.2941	.2819	.2706	.2602	.2506								
37.94	.3335	.3184	.3045	.2918	.2802	.2694	.2594	.2501	.2414						
39.19	.3445	.3288	.3145	.3014	.2893	.2782	.2680	.2584	.2495	.2411	.2333				
40.34	.3550	.3389	.3242	.3107	.2982	.2868	.2762	.2663	.2571	.2485	.2405	.2330	.2260		
41.57	.3653	.3487	.3335	.3196	.3069	.2950	.2841	.2740	.2645	.2557	.2475	.2397	.2325	.2256	.2192
42.70	.3753	.3582	.3427	.3284	.3152	.3031	.2919	.2815	.2718	.2627	.2542	.2463	.2388	.2318	.2252
43.80	.3851	.3676	.3516	.3370	.3235	.3111	.2995	.2888	.2789	.2696	.2609	.2527	.2451	.2379	.2311
44.90	**.3946**	.3767	.3603	.3453	.3315	.3187	.3069	.2960	.2858	.2762	.2673	.2590	.2511	.2437	.2368
45.95	.4039	**.3855**	.3688	.3534	.3392	.3262	.3141	.3029	.2925	.2827	.2736	.2650	.2570	.2494	.2423
46.98	.4129	.3942	**.3770**	.3613	.3469	.3335	.3212	.3097	.2990	.2891	.2797	.2710	.2628	.2550	.2478
48.00	.4217	.4026	.3850	**.3690**	.3542	.3406	.3280	.3163	.3054	.2952	.2857	.2767	.2684	.2605	.2530
48.99	.4306	.4110	.3932	.3768	**.3617**	.3478	.3349	.3230	.3118	.3014	.2917	.2826	.2740	.2660	.2584
49.82	.4390	.4190	.4009	.3842	.3688	**.3546**	.3415	.3293	.3179	.3073	.2974	.2881	.2794	.2712	.2634
50.91	.4470	.4267	.4082	.3912	.3755	.3611	**.3477**	.3353	.3237	.3130	.3028	.2934	.2845	.2761	.2682
51.84	.4556	.4349	.4160	.3987	.3827	.3680	.3544	**.3417**	.3299	.3189	.3086	.2990	.2899	.2814	.2734
52.76	.4637	.4426	.4234	.4058	.3895	.3745	.3607	.3478	**.3358**	.3246	.3141	.3043	.2951	.2864	.2782
53.66	.4718	.4504	.4308	.4129	.3964	.3811	.3670	.3539	.3417	**.3303**	.3197	.3097	.3003	.2915	.2831
54.55	.4795	.4577	.4378	.4195	.4028	.3873	.3729	.3596	.3742	3356	**.3248**	.3147	.3051	.2961	.2877
55.42	.4921	.4697	.4493	.4305	.4133	.3975	.3827	.3690	.3563	.3444	.3333	**.3197**	.3131	.3039	.2952
56.28	.4947	.4722	.4517	.4329	.4156	.3996	.3848	.3710	.3583	.3463	.3351	.3247	**.3148**	.3056	.2968
57.12	.5020	.4792	.4584	.4393	.4217	.4055	.3779	.3765	.3636	.3514	.3401	.3295	.3195	**.3101**	.3012

Wales per inch × courses per inch × 1,296 (square inches per square yard). . . . . (1)

The number of stitches per pound is:

Cotton number × stitches per foot of yarn × 2,520 (feet in cotton No.) . . . . (2)

As stated above, the weight per yard is (1) ÷ (2). Therefore,

$$\text{Weight per yard} = \frac{\text{Wales per inch} \times \text{courses per inch}}{\text{Cotton No.} \times \text{stitches per foot} \times 1.944},$$

$$\text{or, weight per yard} = \frac{W \times C}{1.944 \text{ No.} \times S}.$$

Table — Weight per Square Yard of Plain Ribbed Fabric

Pages 90 and 91

Excluding stitch distortion, the weight per square yard is dependent on the number of the yarn and on the stitches per foot of yarn. This table is worked out for the ranges of such conditions which are likely to be encountered.

The weights in heavy type are those for regular ribbed fabrics. Those to the right are lighter and those to the left are heavier than the regular fabrics.

Many uses of this table will be at once evident. For instance, the question frequently arises, what yarn is required to duplicate fabric of a given weight per square yard? The table shows this, and shows as well the stitches per foot at which the yarn must be run. The next question is, what cut is advisable either for the selection of new machinery or for verifying the adaptability of machinery at hand? Suppose that the required weight is obtainable with number 24 yarn. The use of 24 yarn under regular conditions calls for 48 stitches per foot of yarn as the weight in heavy type shows. But the cut is one-fourth of the stitches per foot of yarn, so the cut for good running conditions with latch-needle machinery is 48 ÷ 4 = 12. Similarly the cut for other conditions may readily be found. If the cut so found is not available, then the yarn may be changed to conform to some cut which is available, all of which may be readily and quickly determined from the table.

This table also shows the weight of flat fabric for the given yarn, but the weight is for *two* square yards and the stitches are for half a foot of yarn. For instance, regular flat fabric made from No. 20 yarn weighs 0.4044 pound per *two* square yards and the stitches per *six inches* of yarn are 43.8.

Weight Formula Transformations

For derivation see bottom of page 89 and top of page 92

This formula may be transformed for the purpose of obtaining any one of the variables when the other four are known, as follows:

$$\text{Courses per inch} = \frac{1.944 \times \text{Weight per sq. yd.} \times \text{Cotton number of yarn} \times \text{Stitches per ft. of yarn}}{\text{Wales per inch}}.$$

$$\text{Cotton number of yarn} = \frac{\text{Wales per inch} \times \text{Courses per inch}}{1.944 \times \text{Stitches per foot of yarn} \times \text{Weight per square yard}}.$$

$$\text{Stitches per foot of yarn} = \frac{\text{Wales per inch} \times \text{Courses per inch}}{1.944 \times \text{Cotton number of yarn} \times \text{Weight per square yard}}.$$

$$\text{Wales per inch} = \frac{1.944 \times \text{Cotton number of yarn} \times \text{Stitches per foot of yarn} \times \text{Wt. per sq. yd.}}{\text{Courses per inch}}.$$

When two threads are used per feed with a different stitch, as is sometimes the case with loop-wheel machinery, the original equation becomes the following, in which No._1 and No._2 represent the different yarns and S_1 and S_2 the corresponding stitches.

$$\text{Weight per square yard} = \frac{W \times C \times (\text{No.}_1 \times S_1 + \text{No.}_2 \times S_2)}{1.944\ \text{No.}_1 \times S_1 \times \text{No.}_2 \times S_2}.$$

If there are two threads No._1 and No._2 but the stitches per foot are just alike then

$$\text{Weight per square yard} = \frac{W \times C \times (N_1 + N_2)}{1.944\, S \times (N_1 N_2)}.$$

These equations are useful in cloth analysis for solving for one unknown, and for checking after all the unknowns are determined.

Weight in Pounds per Square Yard — Formulas for Different Yarn Counts

American .... Wt. per sq. yd. $= \dfrac{\text{Count} \times \text{Wales per inch} \times \text{Courses per inch}}{324 \times \text{Stitches per foot of yarn}}.$

Amsterdam .... " " $= \dfrac{\text{Count} \times \text{Wales per inch} \times \text{Courses per inch}}{203 \times \text{Stitches per foot of yarn}}.$

Cohoes .... " " $= \dfrac{\text{Count} \times \text{Wales per inch} \times \text{Courses per inch}}{101 \times \text{Stitches per foot of yarn}}.$

Cotton .... " " $= \dfrac{\text{Wales per inch} \times \text{Courses per inch}}{1.944 \times \text{Count} \times \text{Stitches per foot of yarn}}.$

Cut .... " " $= \dfrac{\text{Wales per inch} \times \text{Courses per inch}}{0.694 \times \text{Count} \times \text{Stitches per foot of yarn}}.$

Metric, strict .... " " $= \dfrac{\text{Wales per inch} \times \text{Courses per inch}}{1.14 \times \text{Count} \times \text{Stitches per foot of yarn}}.$

Metric, modified .... " " $= \dfrac{\text{Wales per inch} \times \text{Courses per inch}}{2.3 \times \text{Count} \times \text{Stitches per foot of yarn}}.$

New Hampshire .... " " $= \dfrac{\text{Count} \times \text{Wales per inch} \times \text{Courses per inch}}{810 \times \text{Stitches per foot of yarn}}.$

Run .... " " $= \dfrac{\text{Wales per inch} \times \text{Courses per inch}}{3.7 \times \text{Count} \times \text{Stitches per foot of yarn}}.$

Silk, denier .... " " $= \dfrac{\text{Count} \times \text{Wales per inch} \times \text{Courses per inch}}{10{,}272 \times \text{Stitches per foot of yarn}}.$

Silk, dram .... " " $= \dfrac{\text{Count} \times \text{Wales per inch} \times \text{Courses per inch}}{593 \times \text{Stitches per foot of yarn}}.$

Worsted .... " " $= \dfrac{\text{Wales per inch} \times \text{Courses per inch}}{1.3 \times \text{Count} \times \text{Stitches per foot of yarn}}.$

These formulas apply to any knit fabric provided the stitches counted in the wales and courses are the same as those per foot of yarn. For instance, with rib fabric if, as is generally the case, the face wales and courses are counted (and those of the back neglected) then the stitches per foot must be those counted on the needles that knit the face, which are generally the cylinder needles.

DETERMINING WEIGHT PER SQUARE YARD BY WEIGHING

A convenient method of determining the weight per square yard when it cannot be calculated is to cut the fabric by means of a circular die, say $1\frac{3}{4}$ inches in diameter, and weigh the cutting. The area of the disc cut with this size die is 2.405 inches. The weight per square inch $= \frac{\text{Weight of disc}}{2.405}$, and since there are 1296 square inches in a square yard, the

$$\text{Weight per square yard} = \frac{\text{Wt. of disc}}{2.405} \times 1296$$
$$= \text{Wt. of disc} \times 538.8.$$

The balance may be graduated in any unit, such as grains or pounds, as long as it is remembered that the result is in the same unit. As a rule it is convenient to use the pound, both because the goods are generally classified by the number of pounds per dozen, and because the cotton yarn unit of weight is the pound. However, convenience is the principal guide in selecting both the unit of weight and the size of the disc. When accuracy is required, several discs should be cut at one time, in order to get a greater area to weigh, as well as a better average, if the cuttings are from different portions of the fabric, as they may readily be if the fabric is folded with that intention. Also a comparison of the weights of these different discs shows the variation in the weight of the fabric. Of course, when a sample of the fabric is at hand and the yarn and stitches per foot are known, the weight per square yard may be calculated by use of the formula, so that there is no need of weighing; but when the yarn number or the stitches per foot are not known, either one may be obtained from the formula (transformed) after the weight per yard is determined by weighing.

TWO-THREAD KNITTING

Advantages. — Among the advantages of two-thread knitting over single-thread may be mentioned the following:

1. The possibility of obtaining heavier fabric on any one cut, since two threads may be knit more readily than a single thread of the weight of the two threads.

2. Decreased trouble in knitting, owing to the facts that knots and bunches are smaller, that weak places in one yarn are not

likely to part (since the other yarn carries the load), and that even if one yarn does part, the other generally keeps the fabric on the needles.

3. Improved appearance of the fabric, since inequalities in the yarn tend to compensate, and to make clearer work than one yarn of as good quality as the two yarns.

4. More durable fabric, since both threads in a stitch are not so likely to break as a single thread, even though the single thread be somewhat larger.

Disadvantages. — Among the disadvantages are the following:

1. When the yarn is of the same kind, the cost is greater, since double spinning is required.

2. When the machine continues running after one thread breaks, a large piece of fabric may be spoiled.

3. The number of threads is doubled, so the stoppage for lost ends is doubled.

4. Less elasticity.

Plating. — If the work is plated, i.e., if one thread shows on the face of the goods and the other does not, then there are the further advantages that the appearance of the goods is much smoother, and that the thread which does not show may be of less expensive material than the other.

Generally Advisable to Plate Two-thread Work. — The smooth appearance is due to the avoidance of twisted threads in the stitches. Therefore, it is advisable to plate two-thread work, whether it is required to hide one thread or not.

Conditions for Plating. — The conditions for plating are to keep the threads from twisting around each other before entering the needle and in a fixed relative position after they enter it. If these requirements are remembered, the principal difficulties of plating are surmountable by the exercise of observation and judgment.

Testing with One Feed and Contrasting Colors. — A good plan for adjusting the machine is to start only one feed with the kind and size of yarn to be used, as nearly as possible, but in contrasting colors, say black and white. It will be at once evident which thread comes on the face, and if it is not the right one, it may be transposed; also the quality of the plating will be very clear. If it is poor, the machine should be turned very slowly and the action of the yarn observed in order to locate the place where the yarns twist around each other.

Locating Causes of Defects. — As a rule the twisting is overcome or reduced by keeping the yarns from touching each other up to the time they enter the needles, and after that by keeping control of them, either by tension or otherwise.

Separating the Threads in Feeding. — The first thing to do then with any machine is to conduct the yarn to the needles by separate paths, for if two yarns follow the same path, they are sure to twist around each other. Even when they enter the needles they should do so through separate holes in the guide or carrier; or if there is not room for two holes, as is sometimes the case with fine-gauge loop-wheel machinery, the two threads should be kept separate by being guided to the hole at different angles, or by some other such means.

Machines Considered. After the yarn has reached the needles the treatment depends very much on the type of machine which is used. The spring-needle flat-work machines and latch-needle rib machine are considered here.

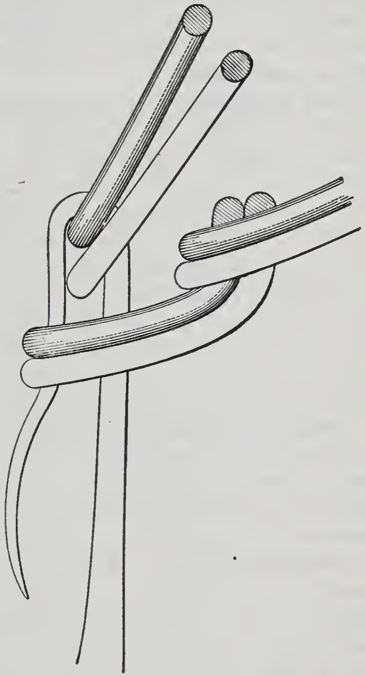


Illustration 1.
Double-thread loops on spring needle. The thread in the head of the needle appears on the back of the fabric.

Illustration 1. — Illustration 1 shows a diagram of a spring-beard needle with the old loop about to cast off over a new double loop consisting of a black and white thread. As shown, the illustration applies to vertical-needle machines, such as the loop-wheel machine, but it may be turned so that the needle lies horizontally with the beard up, when it serves for most machines of the jack-sinker type.

Position of Threads in Spring Needle. — It will be noticed that the black thread, cotton say, is in the head of the needle, and that the white one, say wool, is under it (behind it, if the needle is horizontal); also that in the up-coming stitch the black or cotton thread is on the back. If the positions of the threads in the heads of the needles are reversed, then they will be reversed in the fabric also. Therefore, it is not only necessary to feed the yarns to the needles in the correct relative position but to keep them there, which latter requirement is sometimes difficult, especially with loop-wheel machines.

Yarn Difficulties. — The composition and twist of the yarn are sources of trouble, so the most used materials, namely wool and cotton, should be considered. In the first place there is the tendency of the yarn to untwist, which tendency is generally more pronounced in wool than in cotton. Then in the loop-wheel machine there is a rolling motion imparted by the sinker-bur blade which increases the tendency to twist.

Rolling by Rotary Sinker. — Moreover, there is opportunity to twist, not only when the yarns are feeding over the sinker, but after they get under the needle beard, for the cramp of the needle must be sufficiently open to receive small bunches at least, so it cannot clasp the yarn tightly enough to hold it securely in place.

Helps to Spring-needle Plating. — Some of the helps to good plating on spring needles may be understood from the preceding; that is, needle cramp as close as is permissible, yarns about of a size, and anything which will prevent twisting of the yarns in the uncontrolled space between the sinker and the cast-off.

Treatment of Yarn. — Among the artificial means of preventing twisting is deadening the yarn by emulsionizing, dampening, oiling, etc.; but a better way, although not always available, is to use a gauge of machine as fine as is consistent with good running, so that the stitch may be fairly long, since the loops keep their position much better when the gauge is well filled and the loop is long.

Short Stitches Twist the Most. — This is illustrated by the custom of using eveners or dividers on loop-wheel machines which knit fine yarn with a tight stitch, and of not using them with heavy yarn and a long stitch.

Silk and Worsted. — When it is impractical to use yarn of about the same size, as is generally the case in knitting a silk face and a worsted back, where the cost of an equal-size silk yarn would be prohibitive, then deadening the yarn must often be resorted to.

Casting-off from Spring Needle. — Suppose that the two threads are kept in the correct relative position until they get to the cast-off. This is one of the troublesome places, especially in loop-wheel knitting. By reference to Illustration 1, it will be seen that the old loop has to move up over the new double one without disturbing its own structure or the relative position of the yarns in the new loop. With a needle as closely cramped as the one shown the new loop is comparatively safe, but such a close cramp is impractical; moreover, as the old loop comes up, the black thread on the back is likely to be rolled through upon the face by the friction against the new loop. This is aggravated not only by the upward pull of the fabric, but by the crude action of the cast-off blade.

Comparison of Jack Cast-off and Rotary Cast-off. — Consequently, machines in which the fabric draws at right angles to the needles and in which jack cast-offs are used, do better plating as far as casting-off is concerned. Moreover, they do better work as far as sinking the stitch is concerned, since they are generally equipped with jack sinkers which place the yarn in position and then retire directly, instead of retiring with a rolling motion as does the fixed bur blade. One important factor which counts in favor of the plating on jack-sinker machines is practice, for where jack-sinker machines are used two-thread fabrics are much more common, so that jack-sinker knitters have opportunity to become more expert in this kind of work.

Two Sinker Burs. — Before leaving the loop-wheel machine mention should be made of the use of two sinkers for plating. Owing to the fact that the needle drives the sinker bur, it is inadvisable to overload the latter, and since two-thread work is generally made heavier than single-thread work of the same gauge, it is not uncommon to divide the work of sinking between two burs, in which case the first to feed the needle carries the thread which goes on the back of the fabric.

Short Stitch for Concealed Yarn. — This practice enables making the stitch of the back thread tighter than that of the face thread, which is frequently done and seems to be warranted by the evidently shorter path occupied by the thread on the back of the fabric.

With two sinkers the feed occupies additional space, so that the number of feeds per cylinder is more restricted; and there is increased danger of the yarn dropping out of the needles owing to the increased distance from the first sinker to the cast-off; but there is the advantage that with differently colored yarns, checks and vertical stripes may be made by blocking certain spaces in the face sinker, which floats the face thread on the back of the fabric and lets the back color show through on the face.

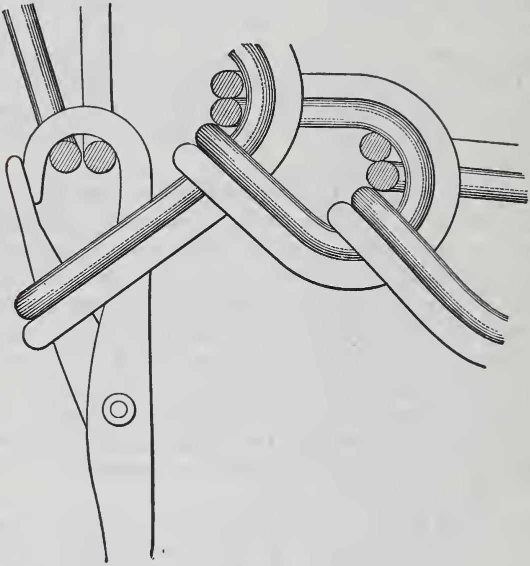


Illustration 2.

Double-thread loops on latch needle. The thread nearest the point of the hook is hidden in the fabric. The dial needle is not shown.

Illustration 2. — Illustration 2 shows a latch needle which has just drawn a double loop for ribbing and which is about to clear the old loop over the new loop.

Position of Thread in Latch Needle. — It will be noticed that in this case the thread which is hidden is toward the latch, or outside, as the needle generally stands; that this thread is hidden between the back and the face instead of being left exposed on the back; and that its path is much shorter than that of the other thread, which probably accounts for the practice of using tension on it in order to improve the plating; although it is doubtful if much difference can be made in the length of yarn fed, since the construction of the machine makes nearly equal lengths imperative.

Two Holes in Carrier. — A good way of keeping the yarns apart before they reach the needles is to use two holes in the carrier, one in the usual position feeding to the inside, and the other feeding out of the bottom of the carrier. In this case it is advisable to withdraw the dial needle sooner than is usual, in order to avoid the danger of catching the dial latch in the hole in the bottom of the carrier. With the threads separated in this way good plating of the cylinder stitches is obtained.

Plating Inside of Rib Fabric. — If plating of the dial stitches also is desired, the tension must be kept on the loops with proper cam arrangement until the dial stitches are cleared. If this requirement is met, the yarn to be hidden will slide up into the head of the dial needle and occupy the position nearest the latch just as it does in the cylinder needle.

Tracing Trouble. — The causes of defective plating may frequently be located from an examination of the fabric containing the defects. Reversal of the yarn before it gets into the needles is generally indicated by a streak along a course. Reversal in clearing the stitch is generally indicated by appearance of the back thread at the edge of the wales at irregular intervals, except when the needle has something to do with the trouble, when the wale will show the defect throughout its length.

TWIST IN FLAT KNIT FABRIC MADE WITH SELF-FEEDING NEEDLES

The yarn generally comes to the knitter on cones. So the subject of twist begins for him with the cone. It will be conceded that the yarn on this cone has a certain amount of twist, either right-hand or left-hand as the case may be. It does not matter whether part of that twist was put into the yarn in coning it or not. This is as true of a bobbin as it is of a cone.

Right-hand Twist. — Right-hand twist is such that if the yarn could be turned into metal, it would look and act like a right-hand screw; that is, by turning it into a board in the direction of the hands of a clock it would draw itself into the wood.

Motion in this direction is called clockwise because it is like that of the hands of a clock.

Left-hand Twist. — Yarn with left-hand twist, if solidified, would have to be turned in the opposite direction in order to make it enter the board, which direction is called anti-clockwise because it is opposed to that of the hands of a clock.

Point of View does not Affect Direction of Twist. — Turning the yarn end for end does not alter the appearance of the twist, so its direction can always be recognized.

Extent of Twist. — The extent of the twist is designated by the number of turns per inch, just as is that of a screw thread.

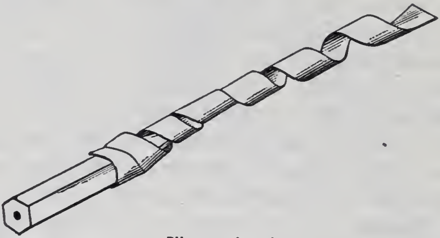


Illustration 1.

Strip of paper pulled lengthwise from a pencil on which it had been coiled in an anti-clockwise direction. The twist in the paper is right-hand, and there are as many twists as there were coils. Similarly, right-hand twist is put into yarn when it is pulled off a cone on which it was wound in an anti-clockwise direction.

Suppose that the piece of yarn is one inch long and has no twist. Then if one end is held and the other is given five complete revolutions, the yarn twist is five to the inch. When released, the yarn will shorten somewhat, so that the twist of that particular piece will be more than five to the inch since then there will be less than an inch of yarn. The actual twist of this piece of yarn or of any piece is the number of complete turns in a given length divided by that length. For instance, if there are twenty turns in two inches, the twist is $20 \div 2$, or 10 to the inch.

Determining Extent of Twist. — A convenient method of determining the number of turns is to cut a known length, say two inches, and hold one end while the other end is untwisted and each turn is counted until the strands are straight. The number of turns divided by the length gives the extent of the twist.

Twist of Yarn is Affected by Delivery from Package. — Consider that the yarn is on the knitting machine, but not yet threaded to run into the needles. As it comes off the cone its extent of twist is changed. Take a pencil and roll a strip of paper around it. Then draw the strip off the pencil endwise as shown in Illustration 1. The strip will have as many twists in it as there were turns around the pencil and the direction of the twist will depend on the direction in which the paper was rolled. Stand the pencil with its point upward, and regard it from the point. Then, as is shown, the paper was wound anti-clockwise, and, evidently, the twist put in the strip is right-hand.

How Cones are Wound. — Now, yarn is generally wound on cones as this strip of paper was wound on the pencil, so when yarn is drawn off from the nose of a cone, it is given one right-handed twist for every complete turn around the cone. Consequently, if the yarn already had right-hand twist, that is increased, and, conversely, if it had left-hand twist, that is reduced.

How Bobbins are Wound. — Bottle bobbins from upright winders are generally wound in the direction opposite to that of the cone. Consequently, when yarn unwinds from a bottle bobbin from the ordinary winder, left-hand twist is put into it to the extent of one turn for every length around the bobbin. If the yarn is right-hand twist, then that is reduced, whereas if it is left-hand twist, it is increased.

Illustration 2. — Illustration 2 shows a bottle bobbin and a cone and how the yarn unwinds from each. The arrows encircling the yarn show the direction of the twist which is put into the yarn by the unwinding, provided the free end of the yarn is kept from turning. From this it follows that the yarn near the cone or bobbin is actually twisted in the reverse direction of that shown by the arrows. If this is not perfectly clear, reference may be made to Illustration 1 which shows how the yarn is twisted coming from the cone. The yarn coming from the bobbin is twisted in the reverse direction. It should be noted that one turn of twist in the yarn is made for each complete turn of yarn around the bobbin, or cone. The average diameter of these packages is about four inches, so one average turn around the package is roughly one foot.

Feeding the Yarn Makes it Revolve. — Now, thread the yarn into a machine with self-feeding needles, such as latch-needle machines for flat work, rib work or hosiery. It will be found that when the yarn is running into the needles, it revolves in the direction in which a corresponding screw would revolve when being screwed into a piece of wood. In other words, yarn with right-hand twist turns clockwise when running from the observer toward the machine, and left-hand-twist yarn revolves

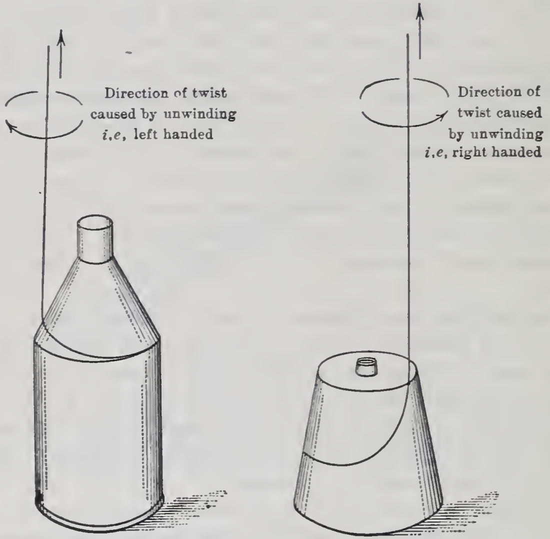


Illustration 2.

anti-clockwise. Moreover, the rate of turning is quite rapid, sometimes amounting to one turn in less than an inch of the yarn travel.

Yarn Twist Most Important in Making it Revolve. — From this it is evident that the influence of the twist of the yarn itself has much more to do with its revolving when entering the machine than the direction of its unwinding from the cone.

Illustration of Yarn-feeding Conditions. — The explanation of this may be determined by considering the conditions and a somewhat similar case. The yarn is drawn into the old loop at the rate of about five feet per second. For a similar case, suppose a wire cable to be inserted in a snugly fitting hole in a piece of wood and then pulled through from the farther side at the rate of five feet per second. Of course, the cable would revolve in the direction dictated by its twist. That is, a cable with right-hand twist, viewed from the entering side of the board, would revolve clockwise, and one with left-hand twist would revolve anti-clockwise.

To carry the illustration still further, suppose that instead of drawing the cable through a closely fitting hole in a board it be

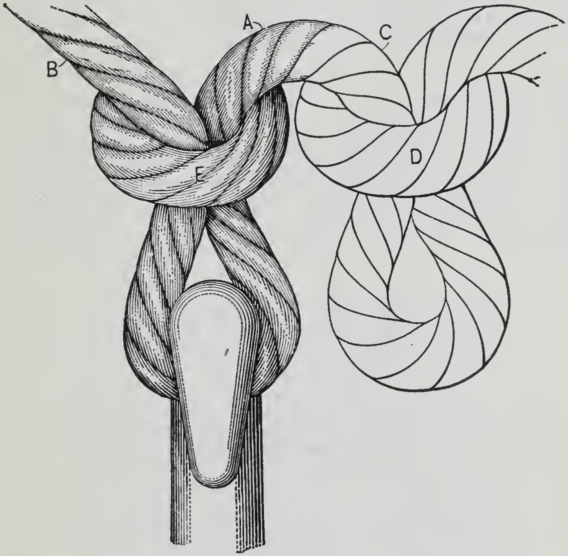


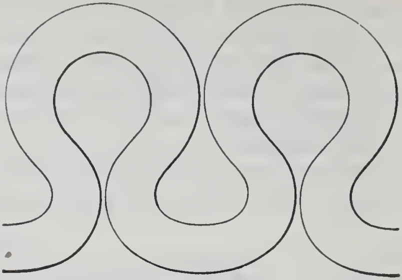
Illustration 3.

Illustration of loop distortion caused by the twist in the yarn. Owing to the inclination of the fibers, the portion marked B slides forward in the loop E in front of loop A. Consequently, loop E is farther forward in the drawing than loop D, so that in the fabric loop E is higher than loop D, and causes left-hand twist in the fabric. Therefore, the twist of the fabric matches the twist of the yarn.

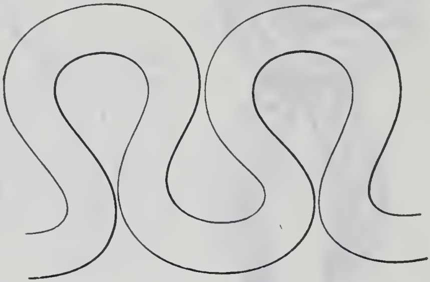
drawn through a closely fitting loop in a rope. Then the rope would tend to twist the cable as just described.

Rule for Revolution of Yarn in Feeding. — Consequently, when yarn is drawn into a stitch, it is revolved according to its twist.

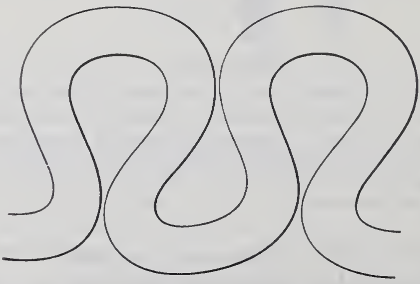
Illustration 3 shows the influence of the twist on the revolution



A. Normal loops.



B. Loops obtained with left-hand twist yarn, and causing left-hand twist fabric.



C. Loops obtained with right-hand twist yarn, and causing right-hand twist fabric.

Illustration 4.

of the yarn as it enters the machine. The hook of the needle has just drawn a new loop through an old one. The yarn has left-hand twist as is shown. The part of the loop which entered the needles first (A) is back of the part which entered last (B), which was drawn in at a velocity of about five feet per second and had to drag a considerable length through the old loop, whereas the other side had but little, if any, dragging to do. Close observation will show that the direction of inclination of the strands of yarn in both the new loop and the old one through which it was drawn tends to slide the entering yarn forward toward the observer, and then to revolve it as it would a left-hand screw in entering. The revolving of the yarn takes some of the twist out of the yarn which is being looped and transfers it to the yarn which is being fed. The moving forward of the entering yarn displaces the loops in a way which produces twist in the fabric, as will be shown.

Flat-fabric Twist caused by Revolving of Yarn in Feeding. — It is evident that B is farther forward than A, but C corresponds to B, so C is farther forward than A. Consequently,

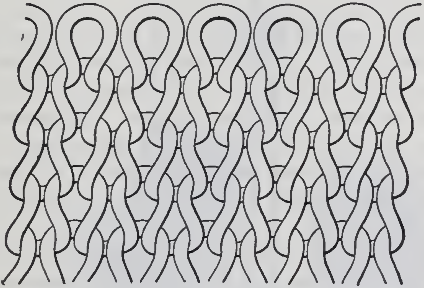


Illustration 5.

Plain flat knit fabric with right-hand twist caused by right-hand-twist yarn.

when the loops are turned upward as they are seen in the face of the actual fabric, loop E will be higher than loop D. That is, with left-hand-twist yarn the left-hand needle loops are highest, and, conversely, with right-hand-twist yarn the right-hand needle loops are highest. Illustration 4 shows the meaning and result of having one needle loop higher than the other. At A two adjoining needle loops are shown in normal position. Fabric with loops like this is not twisted by the causes under discussion.

At B the left-hand loop was higher than the other one, so if the bases of the loops are kept horizontal as shown, which corresponds to keeping the courses horizontal in the fabric, then, evidently, the fabric has left-hand twist. On the contrary, if the right-hand loop was higher as at C, the fabric has right-hand twist. This right-hand twist is shown more fully in Illustration 5.

Rule for Flat-fabric Twist. — From the preceding it follows that yarn with left-hand twist produces fabric with left-hand twist, and yarn with right-hand twist produces fabric with right-hand twist, or the twist of the fabric is like the twist of the yarn.

An interesting question is how much, if any, does the direction of motion of the machine affect the twist of either the yarn or the fabric? Evidently one end of the yarn is in the cloth and the other is in the cone. The cone does not revolve with respect to the yarn and only in the case of some one-feed circular machines does the yarn revolve with respect to the cone.

Effect of Machine Motion on Fabric Twist. — A case of this kind is shown in Illustration 6, which is of a one-feed circular ribber in which the cams revolve anti-clockwise (the conventional direction of motion for such machines). Since the yarn enters the hole in the center of the end of the stud and comes out of the side of the stud, and since the stud revolves, whereas the cones are stationary, it is evident that for each revolution of the machine it must put one turn of twist in the yarn. The arrow in Illustration 6 shows the direction of motion of the machine, from which it is evident that the twist put in the yarn is left-hand.

Some Machines Twist Yarn Slightly. — Consequently, in a machine of this kind the twist put in the yarn is right-hand if the yarn carrier turns clockwise and left-hand if it turns anti-clockwise. This is also true of the ribber with dogless attachment when the cone does not revolve with the yarn carrier. In general, it is true of all machines in which either the carrier (yarn guide) or cone revolves in respect to the other, i.e., in machines in which the cone is stationary and the carrier revolves, or in machines in which the carrier is stationary and the cone revolves.

Some Machines do not Twist Yarn. — When both the cone and carrier revolve together, as in Illustration 7, then the direction of motion of the machine does not affect the twist of the yarn. This comes under the general rule that when the cone and carrier do not revolve with respect to each other, then neither the

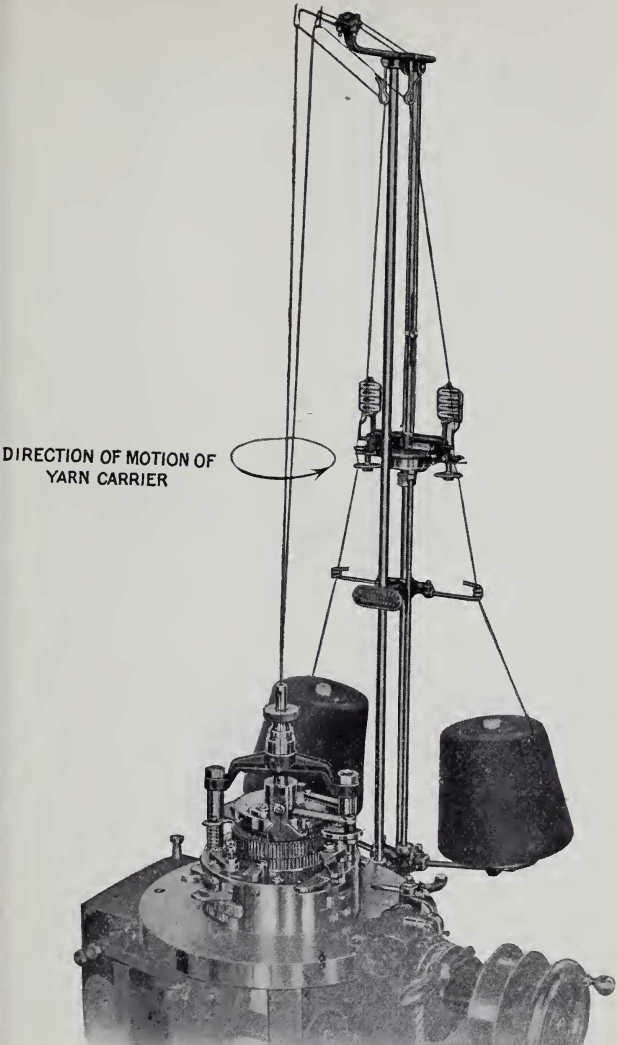


Illustration 6.

Type of machine which twists yarn.

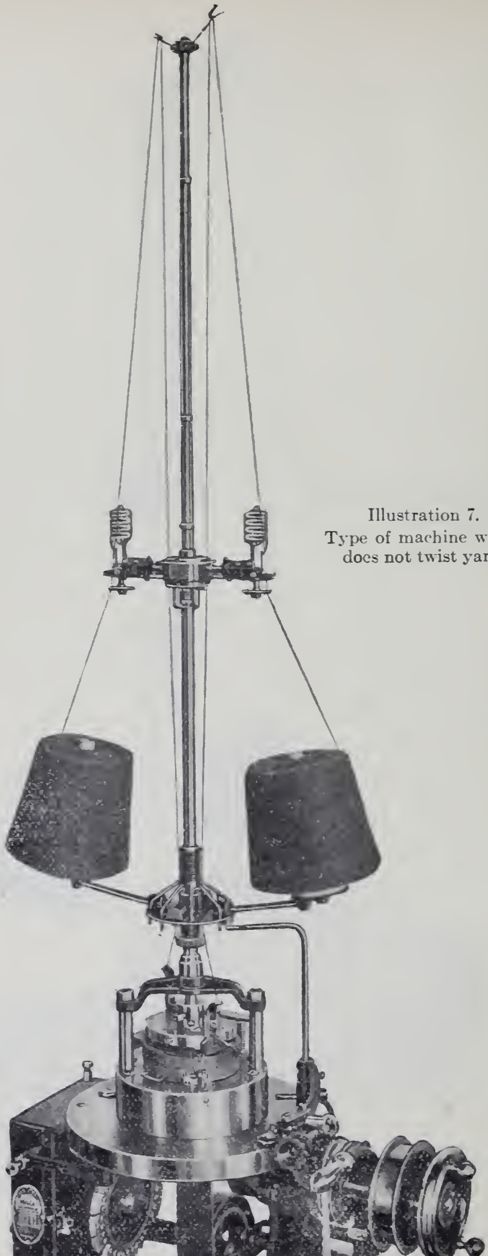


Illustration 7.
Type of machine which does not twist yarn.

direction of motion of the machine nor the relative motion of the different parts of the machine affect either the twist of the yarn or the twist of the fabric. Illustration 7 shows a ribber of the revolving cam type in which the carrier and the cone are stationary with respect to each other, although they both revolve with respect to the head base. The result is the same whether the cams revolve one way or the other or whether the cams are stationary and the needles revolve one way or the other. This is contrary to the notions of some knitters and knitting-machine manufacturers who advocate a particular direction of motion, or a particular type of machine on account of alleged beneficial action on the twist of the yarn.

Machine Motion does not Determine Direction of Yarn Revolution in Feeding. — The fallacy of these arguments may be quickly shown by observing a knot traveling toward the needles during the making of the heel or toe on an automatic hosiery machine. If the yarn has right-hand twist, the knot will revolve clockwise viewed from behind and will continue to revolve so in spite of the fact that the needles revolve first in one direction and then in the other. This is equally true whether the machine be of the revolving cylinder type or of the more common revolving cam type.

Fabric Twist Independent of Machine Motion. — Regarding the effect of the direction of motion of the machine on the twist of the fabric, reference to Illustration 3 shows that it matters not which of the two loops is formed first as far as the resulting twist in the fabric is concerned, for if the right-hand loop is formed last, the side of the loop on the extreme right will be drawn backward instead of forward toward the observer, so the illustration holds true for either case. Naturally, a corresponding conclusion would apply to right-hand-twist yarn as well. Consequently, the direction of motion of the machine has no effect on the twist of the fabric. From this it follows that it makes no difference whether the cams or the needles revolve with respect to the head base, since by any combination only two directions for the formation of the stitch are available and it has just been shown that neither one of these directions has any effect on the twist of the fabric.

Minor Causes of Fabric Twist. — However, it is practically certain that the take-up tension, the yarn tension, the angle at which the yarn is fed and many such details combine to affect the twist of the fabric in ways and to an extent which cannot readily be generalized. Moreover, the cause of what little twist there is in rib fabric seems to manifest itself slightly in flat goods also. This is explained under the title *twist in rib fabric*, which twist is opposite to that of the yarn of which it is composed.

Conclusion. — Consequently, in flat fabric there are generally at least two opposite tendencies; namely, the marked one just described which is to twist in the direction of the yarn twist, and a slighter tendency to twist in the opposite direction. Observations so far indicate that the former generally prevails, but if it is quite weak, then the twist of the fabric becomes opposite to that of the yarn, but there is no inclination of the wales accompanying it. Moreover, the effect is generally so slight as to be unobjectionable.

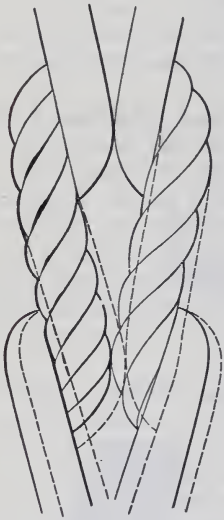


Illustration of one effect of yarn twist on rib fabric twist. The yarn is right-hand twist, which tends to straighten, and to throw the bottom of the stitch to the right as shown by the dotted lines, which puts left-hand twist in the fabric.

TWIST IN RIB FABRIC

Twist in rib fabric is due to a slight untwisting of the yarn instead of to stitch distortion. If the stitch is long, there is a greater length of yarn in it to untwist, so the effect in the fabric is more noticeable.

The manner in which the untwisting of the yarn affects the fabric may be understood by considering one face stitch with the top or round portion upward as in the illustration. The two sides of the loop lie approximately parallel as they enter the next lower loop. Suppose that the twist of the yarn is right-hand. Then the visible strands or fibers will be inclined upward to the right like the threads of a right-hand screw. Consequently, if any of the twist comes out, the bottom of the stitch must turn to the right, and every stitch in the fabric twisting thus puts left-hand twist in the fabric for the wales will then be inclined upward to the left. In other words, the twist of the fabric is opposite to that of the yarn composing it. This can be illustrated nicely by running one cone of left-hand-twist yarn with a set of right-hand-twist yarn. The course made by the left-hand-twist yarn being distinctly different from the other courses, produces the loop effect of an improperly adjusted cylinder stitch cam, but close examination will show the stitches of this course to be twisted opposite to those of the other courses.

Obviously, the weaker the twist in the yarn the slighter will be the twist in the fabric, and it can be reduced by running together two equal threads of equal but opposite twist.

SUMMARY REGARDING TWIST OF KNIT FABRICS

General

The direction of motion of the cylinder and the cams with respect to each other or with respect to the head base is immaterial.

When the yarn carrier revolves with respect to the yarn-supply package, there is a slight tendency to twist the yarn right-hand if the motion of the carrier is clockwise and left-hand if the motion is anti-clockwise, but this tendency is so slight that it is negligible, even on very small-sized machines on which it is the greatest.

The yarn is twisted in coming from the package, right-hand if unwound clockwise and left-hand if unwound anti-clockwise; and the extent of twist is inversely proportional to the length of one complete coil; but, at most, it is insufficient to affect materially either the yarn or the fabric.

When yarn is being drawn by a self-feeding needle, it revolves clockwise if the yarn twist is right-hand and anti-clockwise if left-hand, and thereby transfers some of the twist from the yarn which is forming the loop to the yarn which is just entering. The tendency is strong in hard yarns with well-defined strands. This helps to account for the persistent kinking of some yarn when running into the machine.

Rib Work

The revolving of the yarn in entering seems not to affect the twist of the fabric, but the natural tendency of the yarn in the loops to untwist makes rib fabric twist slightly opposite to the twist of the yarn.

Winder Capacity, in Pounds per Spindle per 9 Hours Actual Time

Nutaper, 1250 r.p.m.

Yarn count	Cotton 195/Y	Worsted 293/Y	Cut 546/Y	Amer. 1.17 Y	Amst. 1.87 Y	Cohoes 3.7 Y	Silk dram .64 Y
	Y means yarn number						
1.0	195	293	546	1.2	1.9	3.7	.6
1.2	162	244	455	1.4	2.2	4.4	.8
1.4	139	209	390	1.6	2.6	5.2	.9
1.6	122	183	341	1.9	3.0	5.9	1.0
1.8	108	163	303	2.1	3.4	6.7	1.2
2.0	98	147	273	2.3	3.7	7.4	1.3
2.3	84	126	234	2.7	4.4	8.6	1.5
2.7	73	110	204	3.1	5.0	9.9	1.7
3.0	65	98	182	3.5	5.6	11.1	1.9
3.5	56	84	156	4.1	6.5	13.0	2.2
4.0	49	73	136	4.7	7.5	14.8	2.6
4.5	43	65	121	5.3	8.4	16.7	2.9
5	39	59	109	5.9	9.4	18.5	3.2
6	32	49	91	7.0	11.2	22	3.8
7	28	42	78	8.2	13.1	26	4.5
8	24	37	68	9.4	15.0	30	5.1
9	22	33	61	10.5	16.8	33	5.8
10	19.5	29	55	11.7	18.7	37	6.4
11	17.7	27	50	12.9	21	40	7.0
12	16.3	24	46	14.0	22	44	7.7
13	15.0	23	42	15.2	24	48	8.3
14	13.9	21	39	16.4	26	52	9.0
15	13 0	20	36	17.6	28	56	9.6
16	12.2	18.3	34	18.7	30	59	10.2
17	11.5	17.2	32	19.9	32	63	10.9
18	10.8	16.3	30	21.1	34	67	11.5
19	10.3	15.4	29	22.2	36	70	12.2
20	9.8	14.6	27	23.4	37	74	12.8
21	8.3	14.0	26	24.6	39	78	13.4
22	8.9	13.3	25	25.7	41	81	14.1
23	8.5	12.7	24	26.9	43	85	14.7
24	8.1	12.2	23	28.1	45	89	15.4
25	7.8	11.7	22	29.3	47	93	16.0
26	7.5	11.3	21	30.4	49	96	16.6
27	7.2	10.9	20	31.6	51	100	17.3
28	7.0	10.5	19.5	32.8	52	104	17.9
29	6.7	10.1	18.8	33.9	54	107	18.6
30	6.5	9.8	18.2	35.1	56	111	19.2

Allowance should be made for lost time according to the quality of yarn and skill of help, which vary so much that a general rule is not given.

Capacity in Pounds per Spindle of Upright Bobbin Winder, 300 r.p.m. of Main Shaft, for 9 Hours Actual Time

Yarn count	Cotton 166/Y	Worsted 249/Y	Cut 465/Y	Amer. Y×1	Amst. Y×1.59	Cohoes Y×3.19	Silk dram Y×.545
	Y means yarn number						
1.0	166	249	465	1.0	1.6	3.2	.55
1.2	138	207	388	1.2	1.9	3.8	.65
1.4	119	178	332	1.4	2.2	4.5	.76
1.6	104	156	291	1.6	2.5	5.1	.87
1.8	92	138	258	1.8	2.9	5.7	.98
2.0	83	125	233	2.0	3.2	6.4	1.09
2.3	71	107	200	2.3	3.7	7.4	1.27
2.7	62	93	174	2.7	4.2	8.5	1.45
3.0	55	83	155	3.0	4.8	9.6	1 63
3.5	47	71	133	3.5	5.5	11.2	1.91
4.0	42	62	116	4.0	6.4	12.8	2.18
4.5	37	55	103	4.5	7.2	14.3	2.45
5	33	50	93	5	8.0	15.9	2.72
6	28	42	78	6	9.5	19.1	3.27
7	24	36	66	7	11.1	22	3.81
8	21	31	58	8	12.7	26	4.36
9	18	28	52	9	14.3	29	4.9
10	16.6	25	47	10	15.9	32	5.5
11	15.1	23	42	11	17.5	35	6.0
12	13.8	21	39	12	19.1	38	6.5
13	12.8	19.2	36	13	20	41	7.1
14	11.9	17.8	33	14	22	45	7.6
15	11.1	16.6	31	15	24	48	8.2
16	10.4	16.0	29	16	25	51	8.7
17	9.8	15.6	27	17	27	55	9.3
18	9.2	13.8	26	18	29	57	9.8
19	8.7	13.1	25	19	30	60	10.3
20	8.3	12.5	23	20	32	64	10.9
21	7.9	11.9	22	21	33	67	11.4
22	7.6	11.3	21	22	35	70	14.7
23	7.2	10.8	20	23	37	74	12.5
24	6.9	10.4	19.4	24	38	78	13.0
25	6.6	10.0	18.6	25	40	80	13.6
26	6.4	9.6	17.9	26	41	83	14.2
27	6.1	9.2	17.2	27	43	86	14.7
28	5.9	8.9	16.6	28	45	89	15.3
29	5.7	8.6	16.0	29	46	93	15.8
30	5.5	8.3	15.5	30	48	96	16.3
32	5.2	7.8	14.5	32	51	102	17.4
34	4.9	7.4	13.7	34	54	108	18.5
36	4.6	6.9	12.9	36	57	115	19.6
38	4.4	6.6	12.2	38	60	120	20.7
40	4.2	6.2	11.6	40	64	127	21.8

Allowance should be made for lost time according to the quality of yarn and skill of help, which vary so much that a general rule is not given.

SUMMARY REGARDING TWIST OF KNIT FABRICS — CONTINUED

Flat Work

The revolving of the yarn in entering tends to twist the fabric the same as the yarn of which it is composed. When twist from this cause does not occur, there is generally a slight twist opposite to the twist of the yarn, due to the cause just mentioned in connection with rib work.

SET

The original underwear mills in America carded and spun their own yarn, and the size of the mill was expressed by the number of sets of cards. A set of machinery was considered to be:

1 set of cards; 1 mule; 2 spring-needle knitting tables, with 2 four-feed cylinders each, i.e. 16 flat feeds in all; preparatory and finishing machinery to match, according to the special conditions, which were too diverse for general classification.

Soon, however, the use of larger cards, the efforts to increase production, the introduction of the latch-needle machine, the use of fine bought cotton yarn instead of mill-spun woolen yarn — all these and other conditions — made the term set as applied to a knitting mill so indefinite that its use decreased. However, there are still many knitting mills which spin their own yarn; and there is much knitting information expressed in the set unit, so a knitter should know not only what a set is but also how much allowance to make in the use of it.

Results of quite extensive investigations of knitting mills making their own yarn exclusively or nearly so, on woolen cards, show a set of machinery — for 48 inches of card width, either actual or reduced from other size cards — to range as follows:

1 set 48-inch cards; mule spindles, 240 to 325; winder spindles, 20 to 40; flat feeds, 14 to 25; sewing machine settings, 6 to 12; preparatory machinery, cuff-knitting machinery, and finishing machinery (other than that mentioned) to correspond.

Among the other machines, which cannot be classified by the set because one is sufficient for a number of sets, may be mentioned a press, a washer, and a hydro-extractor. In addition there are means for final drying, such as drying forms or dry pipes, brushers, dyeing and bleaching apparatus, and some less important machinery according to the work done and the methods used.

The cost of a set of knitting machinery is $10,000, with a variation of 30 per cent either way.

The cost of mill buildings per set is $7000, with considerable variation, frequently on the low side, since popular opinion was that any kind of building was good enough for a knitting mill.

The cost of the site varies so much that generalization cannot be made. In some cases the land is "thrown in" as long as power is paid for.

The horse power required, as is shown with more detail elsewhere in the book, is about 18 per set. When steam power is used, the engine is non-condensing, since the exhaust is used for heating, washing, and drying. One hundred tons of coal per set per year will supply the power and all other heating requirements, if the exhaust is efficiently used. This includes some live steam used during severe weather. Less efficient installations increase the coal consumption as much as 25 per cent. When exhaust steam is not available for heating, washing, and drying, about fifty tons of coal per set are used for those purposes. There is opportunity for economy in the heat and power installations of knitting mills.

It is difficult to determine the water requirements, since the water used is seldom metered, but the following record gives an idea of it.

Large mill for children's fleeces, men's flat cotton underwear and ladies' ribbed vests; made most of its own yarn, washed, dyed, and bleached, used steam power exclusively, used hydraulic elevators, and presses, ran day and night; paid 3c per 1000 gallons of water and used 1,600,000 gallons per set per year.

SPACE ALLOTMENT IN KNITTING MILLS

The figures are from measurements of mills in commercial operation, and are useful for guidance in designing new mills, or for estimating on the real estate charges in figuring the cost of underwear.

The per set figures are probably the most useful, since they afford means of comparison on nearly equal terms, as well as units for proportioning the space according to the producing capacity of the mill.

Space Allotment in Knitting Mills

Total Clear Floor Space, Square Feet

	Raw stock	Picking	Carding	Spinning	Winding and knitting	Washing	Drying	Seaming and finishing	Napping	Packing	Storing	Machine shop	Office	Boiler	Engine	Miscellaneous	Total
A, 4 Set 48 in.	......	960	2750	3,250	2700	660	1080	6971	714	......	......	672	209	1110	777	......	21,853
B, 8 Set 48 in.	9954	1680	4656	4,194	4576	2527	4704	7008	462	5346	16,118	......	399	2014	875	......	64,513
C, 9 Set (6–60 in., 3–48 in.)	......	2950	6240	10,400	3640	2400	1440	9720	960	4972	......	391	680	1700	800	520	46,813
D, 11 Set 60 in.	3298	9572	8779	9,572	9572	1715	3340	9572	2256	8528	25,584	2256	744	966	1290	1091	98,135
Sets 48 in.	**Per Set of 48-inch Card Width. Clear Floor Space, Square Feet**																
A, 4	......	240	687	812	675	165	270	1742	178	......	......	157	52	275	194	......	5447
B, 8	1244	210	582	524	572	316	588	876	58	668	2020	......	50	252	109	......	8069
C, 10.5	......	281	594	990	347	229	134	926	91	474	......	37	65	162	76	50	4456
D, 13.75	240	696	638	696	696	125	243	696	164	622	1861	164	54	70	94	79	7138

This table gives the departmental and total floor space in four representative American knitting mills. The space is shown just as it was measured, and then below, it is shown per set of 48-inch cards, to facilitate space computations on the " set " basis.

Mill *A* was built for the manufacture of percentage flat goods, but was running on men's fleeces when inspected.

Mill *B* was built for the manufacture of woolen underwear and still made some in fine gauges, but the bulk of its output was men's cotton fleeces.

Mill *C* was designed for making woolen underwear, but was running exclusively on men's fleeces, turning out from 300 to 350 dozen per day.

Mill *D* was designed for a general variety of goods, and was making children's fleeces, men's flat cotton underwear, and ladies' ribbed vests.

All of the mills sold through commission houses. None of them was equipped with rib machinery exclusively; but this would not make much difference in the space allotment, so the figures may be taken for ribbed-underwear mills making their own yarn, as well as for flat-goods mills, either woolen or cotton.

Explanation of the per Set Allotment

Storage. — That of mills *A* and *C* was not obtained, but from 500 to 1000 square feet seems advisable, according to the amount of stock to be carried. Mill *B* had more room than it used.

Picking. — Mill *D* picked and garnetted all of its waste, and had room to spare, which accounts for its large space allotment. None of the other mills worked up its own rag waste. Mill *C* had more room than it needed.

Carding. — The figures run close together, but it should be remembered that all of the yarn used was not spun, so slightly more yarn-making space would probably be desirable for a mill making all of its own yarn. In such a case 2000 square feet for yarn making is reasonable, and an approximate rule for dividing it up into picking, carding, and spinning is as 1 is to 2 is to 3.

Spinning. — Mill *C* had some spare room. See paragraph on Carding for remarks on total yarn space which apply to Spinning as well.

Winding and Knitting. — Mill *C* was crowded. A fair allowance is 600 square feet when flat cuff frames are used, and 500 when not. The proportion of winding to knitting space is about as 1 is to 2.

Washing. — An allowance of 200 is generally sufficient. Mill *B* had more than was required.

Drying. — This space depends on the method or methods used for drying, or whether any is done at all. In rare cases washing and drying are not done. In the mills in question the horizontal-dry-pipe method was used. Mill *B* has also a drying room for the use of drying frames, which accounts for the larger space in that mill. When drying frames and drying lofts are used exclusively, the space may run as high as 1000 square feet and over, although 500 is a better average. The use of drying ovens decreases the space and heat needed for drying.

Seaming and Finishing. — Mill *A* had waste room. A fair division when cuff looping is done is 1 to 2 for seaming to finishing. When looping is not done, the proportion of seaming and the total space may be less. An allowance of 1100 square feet is fair average practice for the total when looping is done.

Napping. — This was an afterthought, since fleeces became popular after these mills were built and the machine or machines were generally put wherever convenient. The space for Mill *B* is too small, since all of its product was not napped. The small garment brushers are not included in napping. They were scattered in different places when used.

Packing. — All of these allowances are large, and properly some of each should be classified as storage of finished goods, but these two departments are so closely connected that it is difficult to locate the dividing line.

Storage. — This space is excessive, owing to the facts that Mill *B* had been designed for a larger number of sets than was installed, and Mill *C* had been just recently enlarged but the new machinery was not yet in place. An allowance of 800 square feet is considered ample; 600 is considered an average.

Machine Shop. — This space is generally limited by convenience.

Office. — The close relationship here shown to the capacity is reasonable since all of the mills had the same method of selling, and the accounting methods would probably be much alike.

Boiler. — Mill *A* had waste room, and Mill *D* had a compact battery. The average is between the two.

Engine. — Mill *A* had waste room.

Miscellaneous. — The extent of this is more a matter of accident than design.

Space Conclusion

A total allowance of 7000 square feet per set of 48-inch cards is a fair average allowance, and 4000 seems to be about the minimum.

It will be evident that there is quite a divergence in the space allowances, not only in the departments but in the mills as a whole. This is to be expected; since knitting as an industry is comparatively new in America; since the mills have generally been a growth from a small original mill, often unsuited to the purpose; and since the design of knitting mills presents so many perplexing problems that designers have not found it profitable to devote to it the time necessary for its development. Although success in the knitting business depends on a great many factors more important than too much or too little space, still the space factor is overlooked only at expense which should go to profit and which will ultimately go there when the extent of the loss is realized. Every 100 square feet of floor space costs about $10.00 per year to maintain, which is interest at 6 per cent on a capitalization of $167.00. On the other hand, if the space is insufficient to allow expedition in the conduct of the business, or if it is so poorly arranged as to require more than necessary hands to convey the work, the cost mounts up quickly. Experience indicates the advisability of the use of automatic conveyors more than at present; passageways large enough to avoid congestion, but no larger; storage so arranged as to be available for either raw stock or finished goods; and room for enlargement in at least one direction, and preferably more than one.

HORSE POWER REQUIRED BY VARIOUS MACHINES USED IN KNITTING MILLS

	Horse Power
Picker, wool or bur	4 – 6
Picker, rag	7 – 9
Lapper, 2 Beater	4 – 6
Lapper, 3 Beater	3 –10.5
Lapper, 4 Beater	6 –16
Set cards	1 – 2
Mule spindles per 100	.4– .7
Winders, upright, say 30 spindles	1
Hydro-extractor	2 – 4
Sewing machines, 5	1

The above is from "Manual of Power" by Samuel Webber, published by D. Appleton & Co. and other sources.

Latch-needle Rib Machines

By test

	Horse Power	
Hanger friction, including belts for 4 body machines or 7 ribbers	.273	
Body machine, 9 feed, without shafting	.443	
" " " with shafting and motor	.546	(One motor to about 50 body machines)
Ribber, 2 feed, without shafting	.31	
" " with shafting and motor	.394	(One motor to 50 ribbers)
Winder, 40 spindle, without shafting	.44	
" 40 " with shafting	.713	

Details are as follows: Knitting machines, Wildman, running at about 800 dia. r.p.m.; shafting, $1\frac{15}{16}''$ dia., running at 340 r.p.m.; hanger bearings, $8'' \times 1\frac{15}{16}''$ babbitted and with ring oilers.

POWER FOR KNITTING MILLS

Results in indicated horse power of tests in two mills making men's cotton fleeced underwear and making their backing yarn on wool cards.

	3 Sets 48-in. cards		10.5 Sets 48-in. cards	
	Total	Per set	Total	Per set
Belted shafting load	14.97	5	86.75	8.25
Average load including shafting	39.4	13.1	127.6	12.15
Full load including shafting	50.2	16.7	210.3	20
Average machinery load less belted shafting load	24.43	8.15	85.85	8.17
Full machinery load less belted shafting load	35.23	11.75	123.55	11.75

Generalization of Above

	Average	Full
Mill with less than 5 sets 48-in. cards:		
Machinery load without shafting	8.15	11.75
Shafting load	5	5
Total load	13.15	16.75
Mill with 5 or more sets 48-in. cards:		
Machinery load without shafting	8.15	11.75
Shafting load	8.25	8.25
Total load	16.40	20.00

Subsequent information from other mills confirms the above, except that for general practice in mills of say 8 sets or over, 18 indicated horse power per set is nearer the average total load.

Spring-needle Loop-wheel Knitting Machines

Delivered horse power to run circular spring-needle loop-wheel knitting machines, averaging $6\frac{1}{2}$ feeds per cylinder, 26-gauge cotton flat work, 1200 diametral revolutions per minute.

		110 cyls.	Per cyl.	Per table
110 cylinders	with shafting	33	.30	.60
	shafting alone overhead and under tables 14 to 16	15	.14	.27
	without above-mentioned shafting	18	.16	.33

Proportionate Distribution of Power in a Knitting Mill Making Its Own Yarn

	Per cent horse power
Winding	6.1
Knitting (including rib cuffs and borders)	22
Seaming	6.6
Finishing	12
Washing	4.5
Yarn making	48.8
	100.0

RELATION OF MACHINE GAUGE AND CUT

The term cut is used to designate the needle spacing of circular latch-needle machines, generally with the number of cylinder needles per inch, measured on the circumference of the cylinder. A 12-cut machine has twelve cylinder needles per inch of the outside cylinder circumference generally measured on the cam surface. The dial needles are not involved. For instance, the 12-cut machine might have a dial cut to match the cylinder, or cut half as fine, or have no dial at all. Such details are described in other ways than by the general word cut. This is reasonable since only one side of the cloth is seen at a time — generally the face or cylinder side — and the fineness of the cloth is judged by the number of wales per inch (or other unit) made on the cylinder needles. The use of dial needles does not necessarily change this number of wales, since the dial stitches lie back of the cylinder stitches instead of between them.

The term gauge is used to designate the needle spacing of spring-needle machines, generally in connection with the number of needles per inch-and-one-half of the needle line. An 18-gauge machine has 18 needles per inch-and-one-half of the needle line, whether curved or straight, or whether with one or two sets of needles.

Evidently an inch-and-a-half is one-half greater than an inch, so gauge is one-half greater than corresponding cut, e.g. 12 cut and 18 gauge stand for the same number of needles per inch.

Therefore,
$$\text{Cut} = \text{Gauge} \times \frac{2}{3},$$
$$\text{and Gauge} = \text{Cut} \times \frac{3}{2}.$$

This applies to the fabric as well as to the machine; but spring-needle fabric is generally wider than latch-needle fabric made with the same number of needles per inch, since heavier yarn is generally used on spring-needle machines.

The relation of the yarn numbers for different machines may be determined by comparison of their respective yarn formulas.

For latch-needle circular rib machines

$$\text{Yarn} = \frac{(\text{Cut})^2}{6} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

For spring-needle circular loop-wheel machines

$$\text{Yarn} = \frac{(\text{Gauge})^2}{40}. \quad \ldots\ldots \quad (2)$$

For machines with the same number of needles per inch

$$\text{Gauge} = \text{Cut} \times \frac{3}{2}.$$

Substituting this value for gauge in (2),

$$\text{Yarn} = \frac{\left(\text{Cut}\ \frac{3}{2}\right)^2}{40} = \frac{\frac{9}{4}\,(\text{Cut})^2}{40} = \frac{9}{160}\,\text{Cut}^2.$$

$$\text{Yarn} = \frac{9\ \text{Cut}^2}{160}. \quad \ldots\ldots \quad (3)$$

Dividing (1) by (3)

$$\frac{\text{Yarn for latch-needle rib fabric}}{\text{Yarn for spring-needle flat fabric}} = \frac{\frac{\text{Cut}^2}{6}}{\frac{9\ \text{Cut}^2}{160}} = \frac{160}{54} = 2.96, \text{ say } 3.$$

Therefore *the number of the yarn for latch-needle rib machines is three times the number for spring-needle flat-work machines having the same number of needles per inch.* If 10 yarn is right on 21 gauge, 30 yarn will be right on 14 cut. That is, the diameter of the yarn is about 1.73 greater for spring-needle flat-work machines than for latch-needle rib machines.

GAUGE

Different Standards

The table gives the number of needles per English inch for the gauge given in the extreme left-hand column. For instance, 18-gauge in

French, coarse	is needles per English inch	10.98
French, fine		16.46
Saxon		19.38
English, split		6.00
English, solid		12.00
English, three needle		18.00
American, New England		9.00
Viennese		17.39

Needles per English Inch

Ga.	French		Saxon	English			American	Viennese
	Gros.	Fin.		Split	Solid	3 Needle	New England	
4	2.439	......	4.306	1.333	2.667	4	2	3.865
5	3.049	......	5.382	1.667	3.333	5	2.5	4.830
6	3.659	......	6.458	2	4.000	6	3	5.797
7	4.268	......	7.535	2.333	4.667	7	3.5	6.763
8	4.878	......	8.611	2.667	5.333	8	4	7.729
9	5.488	......	9.688	3	6.000	9	4.5	8.695
10	6.098	......	10.76	3.333	6.666	10	5	9.662
11	6.707	......	11.83	3.667	7.330	11	5.5	10.63
12	7.317	......	12.92	4	8.000	12	6	11.59
13	7.927	......	13.99	4.333	8.666	13	6.5	12.56
14	8.537	......	15.07	4.667	9.333	14	7	13.53
15	9.146	......	16.15	5	10.00	15	7.5	14.49
16	9.756	......	17.22	5.333	10.67	16	8	15.46
17	10.37	15.55	18.30	5.667	11.33	17	8.5	16.43
18	10.98	16.46	19.38	6	12.00	18	9	17.39
19	11.58	17.38	20.45	6.333	12.67	19	9.5	18.36
20	12.20	18.29	21.53	6.667	13.33	20	10	19.32
21	12.80	19.21	22.61	7	14.00	21	10.5	20.29
22	13.41	20.12	23.68	7.333	14.67	22	11	21.25
23	14.02	21.04	24.76	7.667	15.33	23	11.5	22.22
24	14.63	21.95	25.83	8	16.00	24	12	23.19
25	15.24	22.93	26.91	8.333	16.67	25	12.5	24.15
26	15.85	23.78	27.99	8.667	17.33	26	13	25.12
27	16.46	24.70	29.06	9	18.00	27	13.5	26.09
28	17.07	25.61	30.14	9.333	19.07	28	14	27.05
29	17.68	26.52	31.22	9.667	19.33	29	14.5	28.02
30	18.29	27.44	32.29	10	20.00	30	15	28.98
31	......	28.35	......	10.333	20.67	31	15.5	29.95
32	......	29.27	......	10.667	21.33	32	16	30.92
33	......	30.18	......	11	22.00	....	16.5	31.88
34	......	31.10	......	11.333	22.67	....	17	32.85
35	......	32.01	......	11.67	23.33	....	17.5	
36	......	......	......	12	24.00	....	18	
37	......	......	......	12.333	24.67	....	18.5	
38	......	......	......	12.667	25.33	....	19	
39	......	......	......	13	26.00	....	19.5	
40	......	......	......	13.333	26.67	....	20	

Gauge, Machine

Standard			Needles per English inch	Where used in America
Name	Number of needles	Length, inch		
English hosiery, Split	1 × Gauge	3 Eng.	G ÷ 3	Spring-needle flat-cuff machines.
English hosiery, Solid	2 × Gauge	3 Eng.	2 G ÷ 3	Circular loop-wheel knitting machinery, generally.
English hosiery, Three needle	3 × Gauge	3 Eng.	3 G ÷ 3	
French, Coarse (Gros)	2 × Gauge	3 Fr.	2 G ÷ 3.28	
French, Fine (Fin)	3 × Gauge	3 Fr.	3 G ÷ 3.28	
Saxon	1 × Gauge	1 Saxon	G ÷ .929	
Viennese	1 × Gauge	1 Viennese	G ÷ 1.035	
American, New England	1 × Gauge	2 Eng.	G ÷ 2	Trick-needle loop-wheel machinery, locally.

The question what does "gauge" mean is answered by this table. For instance "What does 40-gauge, New England Standard mean?" The second column shows that the number of needles in the gauge length is 40. The third column shows that the gauge length is 2 English inches, and the fourth column shows that the needles per inch are $40 \div 2 = 20$. Again, "What does 24-gauge, three-needle frame mean?" The second column shows that the number of needles in the gauge is $3 \times$ gauge, or 72. The third column shows that the gauge length is 3 English inches, and the fourth column shows that the needles per inch are $3 \times \text{gauge} \div 3 = 72 \div 3 = 24$.

NEEDLES PER INCH OF HOSIERY MACHINES AND RIBBERS MEASURED FROM BACK TO BACK OF NEEDLES

The cut or number of needles per inch of these machines is not much used, but the diameter of the cylinder and the total number of needles is given instead to convey an idea of the fineness of the machine. Those who are not sufficiently familiar with such machinery to form a fair idea of the fineness from this information have to consult tables, which are given in some machine catalogues, or have to work out the cut by dividing the number of needles by 3.14 and then by the diameter. But since the division is generally shirked, since the tables are not always handy, and since comparatively few can remember the cuts for a wide range of sizes and needles, there is a general impression that it is possible to get along without knowing the cut. This impression is correct where experience and experiment are satisfactory guides, but it is impossible to establish a scientific basis of reckoning without knowledge of the cut or the needle spacing.

The following table shows a simple and rememberable method of quickly calculating the cut with sufficient accuracy for all practical purposes.

Dia. of cyl.	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$
	.14	.13	$.11\frac{1}{2}$	$.10\frac{1}{2}$	.10	.09	$.08\frac{1}{2}$	.08	$.07\frac{1}{2}$	.07

Multiply the number of cylinder needles by the number under the diameter and the result will be the cut.

It is unnecessary to bother with the decimal point since the cuts generally range from 3 to 20 so confusion cannot occur. For instance, a $3\frac{1}{4}$-186-needle machine is one of the following cuts, because the rule says multiply by ten, 1.86, 18.6 or 186: but since 1.86 cut is infrequent and since 186 cut is absurd, the result to take must be 18.6. Accurately, the cut is 18.2. The error due to the use of the quick rule is 2 per cent on this size, $3\frac{1}{4}$, and on the $2\frac{1}{2}$ inch also. For the other sizes the error is 1 per cent or under.

The table in the middle of page 129 gives examples worked out by short cuts.

For the other sizes there is not much advantage to be gained by the use of shorter cuts than the multipliers given.

These diameters are from back to back of needle. If the cam-surface diameter is used, take the multiplier of the next smaller size, which will give the cut as closely as is generally equired. For instance, what is the cut of a 160-needle machine $4\frac{1}{2}$ inches in diameter on the cam surface? The multiplier for the next smaller size, $4\frac{1}{4}$, is $7\frac{1}{2}$, which gives 12 cut. The actual cut is 12.15.

Dia.	Needles	Multiplier	Solution	Actual cut	Error
$2\frac{3}{4}$	126	$11\frac{1}{2}$	126 Add 126, one-tenth Add 63, half of one-tenth 1449	14.5	−0.006
3	148	$10\frac{1}{2}$	148 Add 74, half of one-tenth 1554	15.7	−.0104
$3\frac{1}{4}$	136	10	136	13.2	+.021
$3\frac{1}{2}$	128	9	128 Subtract 128, one-tenth 11.52	11.56	−.0104
$3\frac{3}{4}$	146	$8\frac{1}{2}$	146 Subtract 146, one-tenth 1314 Subtract 73, half of one-tenth 1241	12.4	+.0013
4	214	8	214 Subtract 428, one-fifth 1712	17	+.0053
$4\frac{1}{4}$	138	$7\frac{1}{2}$	138 Subtract 345, one-quarter 1035	10.3	+.0013

Yarn for Loop-wheel Machines

Gauge	Light	Average	Maximum	Gauge	Light	Average	Maximum
8	2.1	1.6	1.1	26	22.0	17.0	11.0
10	3.3	2.5	1.7	28	26.0	20.0	13.0
12	4.8	3.6	2.4	30	30.0	22.0	15.0
14	6.5	4.9	3.3	32	34.0	26.0	17.0
16	8.5	6.4	4.3	34	38.0	28.0	19.0
18	11.0	8.0	5.4	36	44.0	32.0	22.0
20	13.0	10.0	6.7	38	48.0	36.0	24.0
22	16.0	12.0	8.1	40	54.0	40.0	26.0
24	19.0	14.0	9.6				

Cuts for Different Diameters and Slots Measured on Needle Line

Dia.	Circum.	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56
2	6.2832	3.1831	3.5014	3.8198	4.1381	4.4562	4.7746	5.0930	5.4113	5.7296	6.0480	6.3662	6.6845	7.0028	7.3210	7.6395	7.9580	8.2760	8.5942	8.9128
¼	7.0686	......	3.1124	3.3953	3.6783	3.9611	4.2440	4.5270	4.8100	5.0928	5.3758	5.6587	5.9417	6.2247	6.5075	6.7905	7.0735	7.3562	7.6393	7.9222
½	7.8540	......	......	3.0557	3.3102	3.5650	3.8195	4.0743	4.3288	4.5835	4.8380	5.0927	5.3473	5.6021	5.8565	6.1110	6.3660	6.6203	6.8752	7.1300
¾	8.6394	......	......	......	3.0095	3.2410	3.4725	3.7040	3.9355	4.1669	4.3983	4.6297	4.8615	5.0930	5.3243	5.5560	5.7873	6.0190	6.2500	6.4820
3	9.4248	......	......	......	......	......	3.1828	3.3953	3.6075	3.8195	4.0318	4.2440	4.4562	4.6683	4.8805	5.0928	5.3050	5.5170	5.7292	5.9415
¼	10.210	......	......	......	......	......	......	3.1342	3.3300	3.5260	3.7218	3.9178	4.1135	4.3095	4.5053	4.7011	4.8970	5.0930	5.2887	5.4848
½	10.996	......	......	......	......	......	......	......	3.0917	3.2737	3.4555	3.6373	3.8193	4.0010	4.1829	4.3648	4.5468	4.7285	4.9105	5.0924
¾	11.781	......	......	......	......	......	......	......	......	3.0555	3.2252	3.3950	3.5650	3.7345	3.9043	4.0742	4.2439	4.4135	4.5833	4.7533
4	12.566	......	......	......	......	......	......	......	......	......	3.0277	3.1830	3.3422	3.5027	3.3608	3.8195	3.9787	4.1378	4.2970	4.4563
¼	13.352	......	......	......	......	......	......	......	......	......	......	2.9957	3.1456	3.2953	3.4451	3.5950	3.7446	3.8945	4.0443	4.1940
½	14.137	......	......	......	......	......	......	......	......	......	......	......	2.9707	3.1122	3.2536	3.3951	3.5366	3.6780	3.8195	3.9610
¾	14.923	......	......	......	......	......	......	......	......	......	......	......	......	2.9483	3.0823	3.2165	3.3505	3.4844	3.6185	3.7525
5	15.708	......	......	......	......	......	......	......	......	......	......	......	......	......	2.9280	3.0555	3.1828	3.3100	3.4372	3.5648
¼	16.493	......	......	Measured on needle line				......	......	......	......	......	......	......	......	2.9100	3.0314	3.1525	3.2738	3.3951
½	17.279	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	3.0092	3.1250	3.2408
¾	18.064	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.9802	3.1000
6	18.850	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.9707
¼	19.635																			
½	20.420																			
¾	21.206																			
7	21.991																			
¼	22.776																			
½	23.562																			
¾	24.347																			
8	25.133																			
¼	25.918																			
½	26.704																			
¾	27.489																			

Cuts for Different Diameters and Slots Measured on Needle Line

Dia.	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86
2	9.2308	9.5495	9.8677	10.1860	10.5040	10.8220	11.1400	11.4580	11.7760	12.0950	......	......	......	......	......
2¼	8.2052	8.4880	8.7710	9.0540	9.3368	9.6200	9.9028	10.1860	10.4680	10.7510	11.0340	11.3170	11.6000	11.8830	12.1650
2½	7.3842	7.6392	7.8937	8.1483	8.4030	8.6577	8.9123	9.1668	9.4215	9.6762	9.9310	10.1850	10.4400	10.6950	10.9490
2¾	6.7133	6.9450	7.1762	7.4080	7.6395	7.8710	8.1022	8.3335	8.5655	8.7967	9.0280	9.2600	9.4915	9.7232	9.9540
3	6.1538	6.3660	6.5780	6.7905	7.0023	7.2148	7.4270	7.6390	7.8512	8.0635	8.2760	8.4880	8.7000	8.9125	9.1245
3¼	5.6809	5.8765	6.0725	6.2680	6.4642	6.6600	7.1470	7.3512	7.2480	7.4433	7.6398	7.8355	8.0313	8.2273	8.9367
3½	5.2740	5.4560	5.3680	5.8195	6.0015	6.1833	6.3653	6.5467	6.7292	6.9110	7.0930	7.2750	7.4568	7.6390	7.8205
3¾	4.9228	5.0925	5.2622	5.4320	5.6020	5.7715	5.9412	6.1110	6.2810	6.4508	6.6205	6.7902	6.9600	7.1302	7.2995
4	4.6153	4.7745	4.9335	5.0928	5.2518	5.4110	5.5702	5.7293	5.8882	6.0475	6.2070	6.3680	6.5250	6.6843	6.8433
4¼	4.3438	4.4936	4.6434	4.7931	4.9430	5.0928	5.2425	5.3925	5.5421	5.6918	5.8418	5.9913	6.1413	6.2910	6.4410
4½	4.1024	4.2438	4.3853	4.5268	4.6682	4.8098	4.9512	5.0925	5.2340	5.3755	5.5172	5.6585	5.8000	5.9413	6.0830
4¾	3.8865	4.0205	4.1545	4.2885	4.4225	4.5565	4.6905	4.8245	4.9585	5.0925	5.2267	5.3608	5.4948	5.6290	5.7628
5	3.6920	3.8193	3.9465	4.0740	4.2010	4.3285	4.4560	4.5830	4.7103	4.8375	4.9650	5.0922	5.2195	5.3470	5.4742
5¼	3.5163	3.6375	3.7588	3.8800	4.0014	4.1225	4.2438	4.3651	4.4865	4.6075	4.7288	4.8502	4.9713	5.0928	5.2138
5½	3.3565	3.4723	3.5880	3.7035	3.8195	3.9350	4.0510	4.1665	4.2824	4.3980	4.5140	4.6290	4.7453	4.8612	4.9768
5¾	3.2105	3.3214	3.4321	3.5427	3.6535	3.7642	3.8750	3.9855	4.0964	4.2070	4.3188	4.4285	4.5392	4.6500	4.7605
6	3.0767	3.1828	3.2890	3.3950	3.5012	3.6072	3.7134	3.8195	3.9255	4.0315	4.1377	4.2438	4.3500	4.4560	4.5620
6¼	2.9537	3.0556	3.1574	3.2593	3.3625	3.4630	3.5650	3.6677	3.7687	3.8705	3.9724	4.0844	4.1760	4.2780	4.3796
6½	.....	2.9382	3.0362	3.1341	3.2320	3.3300	3.4280	3.5257	3.6238	3.7217	3.8196	3.9177	4.0155	4.1135	4.2113
6¾	.....	.....	2.9246	3.0180	3.1123	3.2065	3.3010	3.3952	3.4895	3.5837	3.6782	3.7725	3.8668	3.9612	4.0554

Cuts for Different Diameters and Slots Measured on Needle Line

Dia.	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116
2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2¼	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2½	11.2040	11.4680	11.7130	11.9670	......	......	......	......	......	......	......	......	......	......	......
2¾	10.1860	10.4170	10.6480	10.8800	11.1120	11.3430	11.5630	11.8060	12.0370	......	......	......	......	......	......
3	9.3370	9.5490	9.7612	9.9733	10.1850	10.3970	10.6100	10.8210	11.0340	10.6260	11.4580	11.6710	11.8830	12.0950	......
3¼	8.6195	8.8147	9.0110	9.2067	9.4025	9.5985	9.7945	9.9900	10.1600	10.3830	10.5780	10.7740	10.9700	10.9120	11.3620
3½	8.0025	8.1841	8.3660	8.5480	8.7295	8.9115	9.0937	8.2755	9.4575	9.6398	9.8210	10.0130	10.1850	10.3670	10.5490
3¾	7.4693	7.6392	7.8090	7.9788	8.1481	8.3180	8.4889	8.6575	8.8273	8.9973	9.1670	9.3370	9.5070	9.6765	9.8463
4	7.0028	7.1620	7.3210	7.4801	7.6392	7.7988	7.9578	8.1168	8.2760	8.4353	8.5945	8.7537	8.9128	9.0720	9.2310
4¼	6.5908	6.7407	6.8905	7.0403	7.1898	7.3395	7.4895	7.6393	7.7895	7.9390	8.0890	8.2388	8.3885	8.5383	8.6880
4½	6.2247	6.3660	6.5072	6.6490	6.7902	6.9320	7.0732	7.2145	7.3565	7.4980	7.6395	7.7810	7.9220	8.0638	8.2052
4¾	5.8970	6.0310	6.1650	6.2990	6.4330	6.5670	6.7010	6.8350	6.9690	7.1030	7.2370	7.3710	7.5053	7.6392	7.7733
5	5.6015	5.7290	5.8560	5.9835	6.1110	6.2380	6.3655	6.4930	6.6200	6.7480	6.8750	7.0020	7.1295	7.2570	7.3840
5¼	5.3350	5.4564	5.5775	5.6990	5.8200	5.9412	6.0630	6.1840	6.3053	6.4268	6.5480	6.6692	6.7905	6.9120	7.0330
5½	5.0925	5.2082	5.3240	5.4400	5.5553	5.6710	5.7870	5.9030	6.0190	6.1347	6.2500	6.3660	6.4820	6.5972	6.7132
5¾	4.8715	4.9820	5.0928	5.2037	5.3140	5.4250	5.5357	5.6462	5.7570	5.8679	5.9785	6.0893	6.2000	6.3108	6.4216
6	4.6680	4.7743	4.8805	4.9865	5.0925	5.1990	5.3048	5.4110	5.5170	5.6230	5.7290	5.8355	5.9414	6.0477	6.1540
6¼	4.4816	4.5835	4.6851	4.7872	4.8890	4.9910	5.0928	5.1947	5.2965	5.3987	5.5005	5.6022	5.7041	5.8057	5.9078
6½	4.3095	4.4073	4.5053	4.6033	4.7010	4.7990	4.8972	4.9950	5.0930	5.1910	5.2890	5.3870	5.4850	5.5828	5.6810
6¾	4.1496	4.2440	4.3383	4.4327	4.5268	4.6213	4.7155	4.8098	4.9045	4.9987	5.0928	5.1873	5.2814	5.3760	5.4704

Cuts for Different Diameters and Slots Measured on Needle Line

Dia.	118	120	122	124	126	128	130	132	134	136	138	140	142	144	146
2	.....	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2¼	.....	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2½	.....	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2¾	.....	....	......	......	......	......	......	......	......	......	......	......	......	......	......
3	.....	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3¼	11.5570	11.7530	11.9490	12.1450	......	......	......	......	......	......	......	......	......	......	......
3½	10.7300	10.9130	11.0940	11.2760	11.4570	11.6400	11.8220	12.0300	......	......	......	......	......	......	......
3¾	10.0160	10.1860	10.3550	10.5250	10.6940	10.8640	11.0340	11.2040	11.3740	11.5430	11.7130	11.8830	12.0530	......	......
4	9.3902	9.5495	9.7090	9.8680	10.0270	10.1860	10.3450	10.5040	10.6630	10.8220	10.9820	11.1410	11.3000	11.4590	11.6180
4¼	8.8380	8.9878	9.1373	9.0175	9.4370	9.5870	9.7370	9.8867	10.0360	10.1860	10.3360	10.4850	10.6350	10.7850	10.9350
4½	8.3468	8.4880	8.6298	8.7710	8.9125	9.0540	9.1956	9.3370	9.4785	9.6200	9.7620	9.9030	10.0440	10.1860	10.3270
4¾	7.9070	8.0412	8.1752	8.3090	8.4430	8.5770	8.7118	8.8453	8.9798	9.1137	9.2475	9.3810	9.5155	9.6500	9.7840
5	7.5115	7.6390	7.7660	7.8930	8.0210	8.1480	8.2753	8.4023	8.5300	8.6570	8.7850	8.9120	9.0390	9.1665	9.2940
5¼	7.1542	7.2757	7.3967	7.5182	7.6395	7.7608	7.8820	8.0050	8.1245	8.2455	8.3670	8.4880	8.6095	8.7308	8.8520
5½	6.8290	6.9450	7.0603	7.1761	7.2920	7.4077	7.5235	7.6394	7.7550	7.8707	7.9865	8.1025	8.2180	8.3335	8.4495
5¾	6.5320	6.6415	6.7517	6.8643	6.9750	7.0860	7.1968	7.3072	7.4180	7.5288	7.6397	7.7502	7.8610	7.9718	8.0825
6	6.2600	6.3600	6.4720	6.5780	6.6840	6.7905	6.8967	7.0028	7.1088	7.2150	7.3210	7.4270	7.5332	7.6395	7.7455
6¼	6.0098	6.1117	6.2133	6.3154	6.4170	6.5190	6.6208	6.7228	6.8248	6.9265	7.0285	7.1303	7.2321	7.3340	7.4358
6½	5.7788	5.8762	5.9747	6.0728	6.1708	6.2685	6.3665	6.4645	6.5622	6.6602	6.7583	6.8562	6.9542	7.0520	7.1500
6¾	5.5648	5.6590	5.7532	5.8473	5.9417	6.0361	6.1308	6.2248	6.3192	6.4133	6.5078	6.6021	6.6964	6.7908	6.8852

Cuts for Different Diameters and Slots Measured on Needle Line

Dia.	148	150	152	154	156	158	160	162	164	166	168	170	172	174	176
2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2¼	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2¾	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3¼	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3¾	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4	11.7770	11.9360	12.0950	......	......	......	......	......	......	......	......	......	......	......	......
4¼	11.0840	11.2340	11.3840	11.5350	11.6840	11.8340	11.9830	12.1330	......	......	......	......	......	......	......
4½	10.4680	10.6100	10.7510	10.8930	11.0340	11.1760	11.3170	11.4580	11.6000	11.7420	11.8830	12.0240	......	......	......
4¾	9.9178	10.0520	10.1860	10.3200	10.4540	10.5870	10.7210	10.8550	10.9900	11.1240	11.2570	11.3920	11.5250	11.6600	11.7940
5	9.4210	9.5490	9.6760	9.8030	9.9308	10.0480	10.1850	10.3130	10.4400	10.5660	10.6940	10.8210	10.9480	11.0750	11.2040
5¼	8.9730	9.0943	9.2160	9.3370	9.4580	9.5800	9.7010	9.8220	9.9430	10.0640	10.1850	10.3060	10.4270	10.5490	10.6700
5½	8.5650	8.6810	8.7965	8.9122	9.0280	9.1440	9.2595	9.3750	9.4910	9.6070	9.7230	9.8385	9.9538	10.0700	10.1850
5¾	8.1930	8.3040	8.4145	8.5252	8.6360	8.7470	8.8570	8.9680	9.0780	9.1900	9.3050	9.4110	9.5220	9.6325	9.7433
6	7.8513	7.9575	8.0638	8.1700	8.2760	8.3820	8.4880	8.5940	8.7000	8.8060	8.9121	9.0183	9.1247	9.2305	9.3365
6¼	7.5378	7.6398	7.7413	7.8431	7.9450	8.0470	8.1490	8.2505	8.3523	8.4543	8.5562	8.6580	8.7600	8.8620	8.9638
6½	7.2480	7.3460	7.4440	7.5420	7.6400	7.7380	7.8358	7.9333	8.0317	8.1296	8.2272	8.3252	8.4231	8.5210	8.6193
6¾	6.9795	7.0735	7.1680	7.2622	7.3567	7.4510	7.5452	7.6397	7.7340	7.8280	7.9225	8.0168	8.1110	8.2052	8.2998

Cuts for Different Diameters and Slots Measured on Needle Line

Dia.	178	180	182	184	186	188	190	192	194	196	198	200	202	204	206
2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$2\frac{1}{4}$	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$2\frac{1}{2}$	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$2\frac{3}{4}$	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$3\frac{1}{4}$	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$3\frac{1}{2}$	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$3\frac{3}{4}$	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$4\frac{1}{4}$	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$4\frac{1}{2}$	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
$4\frac{3}{4}$	11.9270	12.0610	......	......	......	......	......	......	......	......	......	......	......	......	......
5	11.3300	11.4570	11.5850	......	......	......	......	......	......	......	......	......	......	......	......
$5\frac{1}{4}$	10.7920	10.9130	11.0340	11.1550	11.2760	11.3970	11.5190	11.6400	11.7620	11.8830	12.0040	......	......	......	......
$5\frac{1}{2}$	10.3020	10.4160	10.5330	10.6480	10.7640	10.8800	10.9950	11.1110	11.2260	11.3430	11.4580	11.5740	11.6900	11.8050	11.9210
$5\frac{3}{4}$	9.8540	9.9642	10.0750	10.1850	10.2960	10.4600	10.5170	10.6280	10.7380	10.8500	10.9600	11.0720	11.1820	11.2930	11.4030
6	9.4430	9.5490	9.6550	9.7610	9.8670	9.9730	10.0790	10.1850	10.2920	10.3970	10.5040	10.6100	10.7150	10.8220	10.9270
$6\frac{1}{4}$	9.0652	9.1670	9.2690	9.3710	9.4730	9.5748	9.6768	9.7782	9.8803	9.9820	10.0840	10.1860	10.2870	10.3890	10.4920
$6\frac{1}{2}$	8.7170	8.8150	8.8248	9.0110	9.1090	9.2070	9.3045	9.4025	9.5010	9.5990	9.6968	9.7945	9.8925	9.9900	10.0870
$6\frac{3}{4}$	8.3940	8.4880	8.5828	8.6770	8.7710	8.8654	8.9600	9.0540	9.1483	9.2428	9.3370	9.4313	9.5258	9.6200	9.7142

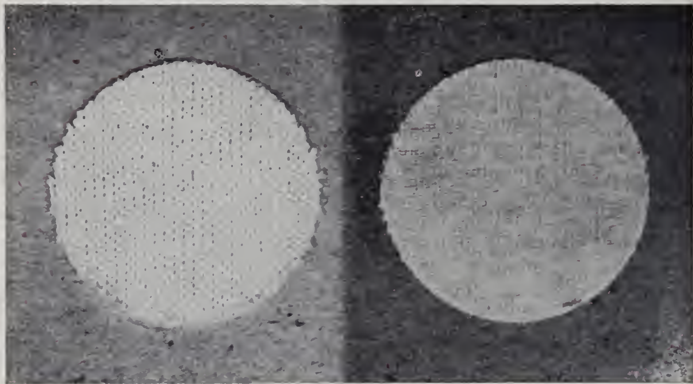
Cuts for Different Diameters and Slots Measured on Needle Line

Dia.	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236
2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¼	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¾	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3¼	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3¾	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4¼	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4¾	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5¼	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5½	12.0360	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5¾	11.5140	11.6250	11.7350	11.845	11.956	12.067	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	11.0340	11.1400	11.2460	11.352	11.458	11.564	11.670	11.776	11.883	11.988	12.095	.....	.....	.....	.....
6¼	10.5940	10.6950	10.7960	10.897	11.000	11.102	11.204	11.306	11.407	11.509	11.612	11.714	11.815	11.916	12.018
6½	10.1360	10.2840	10.3820	10.480	10.577	10.675	10.774	10.872	10.970	10.167	11.165	11.264	11.361	11.459	11.556
6¾	9.8090	9.9030	9.9970	10.092	10.186	10.280	10.374	10.468	10.563	10.656	10.752	10.845	10.940	10.865	11.128

Cuts for Different Diameters and Slots Measured on Needle Line

Dia.	238	240	242	244	246	248	250	252	254	256	258	260	262	264	266
2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2¼	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2¾	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3¼	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3¾	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4¼	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4¾	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
5¼	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
5½	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
5¾	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
6	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
6¼	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
6½	11.655	11.753	11.851	11.948	12.046	......	......	......	......	......	......	......	......	......	......
6¾	11.224	11.317	11.412	11.505	11.600	11.695	11.788	11.883	11.976	12.072	......	......	......	......	......

Range of Fabrics from the Same Gauge or Cut



1 2

Attention has been called elsewhere to the fact that the width of the wale and, consequently, the width of the fabric are proportional to the diameter of the yarn. Since this may seem questionable in view of the general impression that the cut is important in the determination of the width of the wale and of the fabric, the above illustrations are given of two fabrics made on the same cut, namely 14, but with different sizes of yarn, and different lengths of stitch. No. 1 is made on a spring-needle jack-sinker machine, which is adaptable to heavy yarn; whereas No. 2 is made on a latch-needle rib machine, for which light yarn is suitable. The fact that the fine sample is made on a rib machine does not make the comparison unfair, for although there are in the machine 28 needles to the inch, counting cylinder and dial, the fabric is no finer than it would be if it were knit flat with 14 needles to the inch, since the stitches from the dial needles lie on the back of the fabric, and, consequently, cannot be seen. It is obvious therefore that determinations of the needle spacing, or the gauge, from the spacing of the wales may be entirely misleading.

YARN FOR FLAT COTTON FLEECED GOODS

Gauges 20 to 28 Inclusive

Since three threads per feed are used in making ordinary fleeces and since the relations of these threads are not standardized, but rather are determined by the equipment of the mill, by the weights of garment called for by the trade, and by other conditions foreign to the actual knitting, the following tabulation is given of combinations of yarns used in actual practice by representative knitting mills, and yarns obtained by rules which agree closely with the best practice.

Yarn for Flat Cotton Fleeced Goods

1	2	3	4	5	6	7
Gauge	Face	Binder	Backing	Backing by rule $\frac{G^2}{9}$	Combined face	Combined face by rule $\frac{G^2}{40}$
20	20	30	5.00	4.45	12.0	10.0
22	22	30	5.47	5.38	12.7	12.1
22	22	30	6.00	5.38	12.7	12.1
22	22	30	5.20	5.38	12.7	12.1
22	26	26	7.70	5.38	13.0	12.1
24	26	30	5.50	6.40	13.9	14.4
24	26	30	6.50	6.40	13.9	14.4
24	22	30	6.12	6.40	12.7	14.4
26	28	28	6.50	7.50	14.0	16.9
28	30	60	9.45	8.70	20.0	19.6

Columns 1, 2, 3 and 4 show the actual practice. The stitches per foot of yarn and the weights per dozen were not obtained, or when obtained, were rejected owing to incompleteness or inaccuracy. Indeed, the weight per dozen is unsatisfactory without information as to how many square yards of fabric make up the dozen.

Column 5 gives the number of the backing yarn obtained by the rule Cotton number of backing yarn $= \frac{\text{Gauge}^2}{9}$, which represents the average. The constant for practical extremes ranges from 6 to 10.5. Consequently, if the heaviest advisable backing is desired, divide the square of the gauge by 10.5. This is not to be taken as the heavy limit, but it is inadvisable to attempt to use heavier yarn commercially without trying it on the machine. The backing yarn is generally made in the knitting mill, where it is customary to number it in grains or in some other number than the cotton number. Simple rules for transformations into the standards used are given elsewhere.

Column 6 gives the single-thread equivalent of the face and binder actually used.

Column 7 gives the regular single thread for the gauge.

The similarity of Columns 6 and 7 is marked. It is also noticeable that the face thread used is the same as the gauge, or very nearly so; consequently, a rough rule *for the range of gauges given* is to make the face thread the same as the gauge, use a binder about number 30 or under, and use gauge squared divided by 9 for the backing, varied, if necessary, in order to obtain the desired weight after it is known what weight the above combination gives. It should be remembered that a change in weight in the backing should be proportionally twice that desired in the goods, since the backing constitutes only half of the fabric by weight.

For gauges other than those given above, the same rule for backing will probably hold; but for the face yarn it is advisable to derive the equivalent single face yarn by the rule: Cotton number equals gauge squared divided by 40, and then split the face into two threads of which the binder should be the lighter. This division into the two threads is readily done by those who can reverse the rule that the single equivalent thread equals the product of the two divided by their sum, but those who are not familiar with such operations may use the table given elsewhere of the single equivalent of two yarns.

SINKER BUR

The sinker bur is an angular gear having for teeth tempered steel blades with a slight hook, called a nib, for controlling the yarn during the operation of pushing it between the needles and up under the beards. The bur body is generally made of bronze to facilitate cutting, and is provided with a hardened steel bushing to insure against sticking, to provide for long wear and to enable replacement.

The blades are radial and straight (plane), so the length of stitch is limited; therefore good design and adjustment are necessary for good running. Moreover, they are not adjustable, so the operator has no choice regarding the spacing of the blades.

The operator can adjust the bur in and out, also up and down, can rotate it on a horizontal axis, and can generally throw the top of the bur in or out of the needles with respect to the bottom of the bur to a slight extent.

The bur bends the needles backward with the reaction of being driven, and pushes the needles inward with the reaction of feeding the yarn. If the needles are displaced backward too far, the bur over-reaches and the blades get in under the beards, which causes serious trouble. If the inward bend of the needles were slight and constant, no trouble would result; but it is not constant because it depends on the push of the yarn, which increases with increase of yarn diameter or increase of tension and vice versa. Consequently there is always some variation in the inward bend of the needle, since the yarn tension is never constant, and since the diameter is seldom uniform except in the very best yarn. Evidently, inward bending of the needle shortens the length of the loop drawn, in proportion to the extent of the bending, and makes cloudy fabric. This inward bend of the needle, which causes defective fabric, and this backward bend, which causes broken needles and other waste, are the two most serious objections to the loop-wheel machine; and together do much to offset its advantages of high speed, durability and adaptability to change of size, gauge and kind of work. Moreover, there is the still further disadvantage that a poorly designed or improperly adjusted sinker aggravates the troubles just mentioned.

The diameter of the sinker bur should not be greater than is necessary to enable driving it with security and still to get the yarn surely under the needle beard and leave the loop fully drawn in the head of the needle. There are different opinions as to how far below the point of the beard the yarn should begin to draw the loop. If a low point is selected, the drawing is facilitated by the round shank of the needle; but a low point needs a large bur, which increases the number of loops drawn at a time, and increases the backward bend of the needle. If the drawing of the loop is begun well up toward the point of the beard, the diameter of the bur must be less, but there are the disadvantages of drawing over the needle eye, which extends down a little way below the point of the beard; the possibility of splitting the yarn on the point of the beard, which causes a partial tuck; and the possibility of feeding it up over the beard, which causes drop stitches or a press-off. Evidently with a short stitch, the diameter of the bur must be large in order to have enough blades in mesh for secure driving, and in order to obtain sufficient lift for the yarn. On the other hand, for a deep stitch a small diameter is advisable, since the lift is increased by sinking the bur deeper, and since a large bur would put so many blades in mesh that it would cramp itself. Consequently, the length of stitch to be run has much to do with determining the diameter.

Theoretically, the blades should be helical, so that when in mesh they would be nearly parallel to the needles. English sinker burs with soldered blades are sometimes made this way by bending the exposed portion of the blade, but since such bending is practically impossible with the well-tempered blades called for by American practice, and since the cutting of narrow helical slots and bending of blades to correspond is not deemed practical, helical blades are not used in American practice. Consequently, a part of the freedom of the bur in the needles is lost through the difference of inclination of the blades in mesh. From this it follows that the action of the bur in the needles may be made freer by reducing the vertical height in the needles, which may be done by bending the sinker bur bracket upward in machines where flexible brackets are used, or by packing the sinker stand outward where no such provision is made.

However, there is an objection to reducing too much the vertical height of the blade in mesh, since this reduction increases the danger of over-reaching; as is seen from consideration that the bur, although like a gear, has a large amount of back lash (play, in the needles) as compared to a gear. This back lash is reduced by tipping the bur so that the tops of the blades are inclined backward with respect to the motion of the needles. This tipping brings the rounded part of the blade where it will strike the approaching needle in case of a pull back, and will help to keep the bur in mesh, instead of allowing the nib of the bur to over-reach and shear off a needle beard, in which case it is likely to continue to over-reach until the machine is stopped and the bur is reset. If the blade has insufficient vertical depth in the needles, the bur cannot be tipped enough for secure running. This gives a clue to one of the most important points in setting a sinker. That is, that the shoulder of the blade should enter near the approaching needle, whereas the nib of the blade should enter near the passed needle, when the bur is set at the required depth. It is advisable to try this before putting in the yarn as well as after.

When this requirement is met, the nib should leave the loops in the heads of the needles and should retire without pulling the loops and without touching the needles. If it does snap the needle on either side, the loop is almost sure to twist or drop and moreover to make rough work, by the formation of unequal stitches.

It is well to adjust the bur and run the machine without yarn or cloth in order to observe the action of the bur, which should run uniformly without grating the needles, without bucking them as the blades enter, without rippling them as the nibs retire and with but slight bowing action opposite the center of the bur. If the shoulder bucks the needles, the bur may be too coarse, or the top may be tipped backward too far. If it bows the needles too much, it is said to be gathering them, i.e., pinching them together. This is undesirable, since the yarn cannot be fed freely, so that weak places are likely to part at the sinker and knots are likely to catch, either of which often breaks the yarn. If the needles are rippled by the retiring nibs, the indication is either that the bur is coarse and is pushing the leaving needle forward, or that the bur is fine and is holding back the oncoming needle. This last fault is worse than the first, since if the bur is tight without the yarn, it will be still tighter when it is feeding the yarn, because the considerable force required to draw the loop has to be transmitted by the flexible needles, which bend backward some, and so permit the leaving nib to "pick" the oncoming needle still more; whereas if the leaving nib is pushing ahead slightly when it is running without yarn, it may be drawn back into its proper position when the yarn is being fed.

If the bur runs properly without the yarn, it should then be tried with the yarn, either when the cloth is not on the machine, by turning the cylinder by hand, or by trying it with the cloth and power on. This depends on the skill and experience of the operator and on the yarn and stitch used. Some adjusters use a magnifying glass and make exhaustive tests before putting on the power. Others, especially with light yarn, will put a sinker on the stud, throw on the power, and make all adjustments with the machine running at full speed. The best way is undoubtedly to set the bur as carefully as possible before the power is on, make sure that it forms the loop freely and properly and then observe it when it is run with power. The action of the needles in mesh should be noted by inspection from above their heads. They will bow inward more than when the bur was running free and the extent of the bowing will fluctuate according to the tension on the yarn and the lack of uniformity in its diameter. But the general shape of the needle line in the bur should not change to a considerable extent. If it does so, becoming almost angular at times, then there is a cramping action which should be eliminated if possible.

There are many causes for this violent pushing-inward of the needle. The yarn has to be dragged over the blades and around the shanks of the needles with a velocity which varies from one and one-half times that of the needles, at the entrance of the yarn, to zero velocity when the loop is fully drawn. The extent of the dragging, sliding, and rubbing is seldom realized. But some conception of it is necessary in order to understand how to reduce it.

The edges of the blades may be too sharp. Theoretically, they should be half round, but practically they are not so, since in the punching one edge is slightly rounded and the other is left with a sharp fin. In the subsequent tumbling the already rounded edge becomes still more rounded, but the sharpened edge does not always get enough tumbling to bring it into proper shape. Consequently, even when the edge is smooth, it may be angular enough to retard the yarn unduly and thus increase the work of sinking the loop. If in addition to this the roughness is not taken off the edge of the blade, the case is bad indeed, for the work of sinking the loop will not only be much increased, but the yarn will be scraped and cut, especially at knots; and an occasional leaving nib will pull a long loop by stealing from the already formed loops, and will thus make a loose loop on the back of the fabric with tight stitches on each side, which latter are likely to get cut at the cast-off.

Blades which are improperly tempered may appear all right, but may become nicked with use, and so may act as if improperly tumbled.

Sometimes during the hardening of the blades a black oxide forms and does not come off in the tumbling. The roughness of this oxide will sometimes put severe friction on the yarn.

Needles which are rusted, tarnished, or insufficiently polished will sometimes put so much tension on the yarn that the sinker will appear to be improperly set. Also, needles which are cramped too tightly, or are roughened in the cramp by improper milling or by oxide, will resist the entrance of the yarn. The resistance increases the inward bend of the needle, which in turn increases the cloudiness of the fabric and invites " smashes."

If the sinker runs all right with the yarn in position, it should be tested for a slight overload, which testing is generally done by turning the cylinder with one hand while a finger of the other hand is held on the bur to retard it slightly. If it is properly set, it will strike the oncoming needle first with its shoulder; but if it is improperly set, the nib or the whole edge of the blade will catch and buck the needle out of line inwardly. It is unsafe to run a bur so set, since overloads are sure to occur; and a bur so set will neither avoid trouble nor extricate itself, but will get into deeper trouble after it gets started.

If the sinker stands a reasonable overload, the next consideration is the sinker shaft spring. All machines are provided with this, for the reason that by retention of the adjusting nut against the stop it provides in combination with the nut a convenient means of adjusting the bur for depth. Moreover, probably the majority of knitters consider that the spring is useful for relieving the sinker when a load-up occurs, by allowing it to back part way out of the needles. Consequently, the spring is generally adjusted to keep the bur at the required depth under ordinary circumstances, but slack enough to allow it to back out and drop its load if this gets so heavy that serious damage would result. Of course, if the spring is too slack, it may allow the bur to back out and shorten the stitch unnecessarily, which is the fault with the use of slack springs. However, it is generally admitted that for good speed and especially with fairly heavy yarn, much damage can be averted by judicious adjustment of the spring.

A common difficulty with sinker burs is to get blades of the proper thickness. Bad results follow the use of blades which will not go down into place as well as blades which are loose. If it is necessary to use blades which are a trifle oversize, they can sometimes be assisted into position by boiling both the blades and the bur bodies in a solution of washing soda. On the contrary, if the blades are very loose, they should not be used at all, since they will make serious trouble; but if slightly loose and no others are available, the bodies may be put on an arbor and filed slightly with a dead smooth file, which will throw a slight bur over into the slots so that the blades will fit nicely.

LANDER BUR

The lander bur follows the sinker and raises the old stitch up on the point of the beard while the latter is held into the eye by the presser.

The requirements to be met in adjusting the lander may be understood by considering its location. It runs closer to the leads — or cylinder if a trick-needle machine is used — than any of the other stitch-forming burs, since it is necessary for it to reach low in order to raise the old stitches surely, instead of punching through the fabric. On the upper side it comes very near to the presser, since it has to land the stitch while the beard is sunk in the eye, for raising the stitch before will make tuck stitches and raising after will not complete the new stitches. Moreover, the needles in the location of the lander have not only to drive the lander, but also to withstand the resistance of the presser, which holds them inward and backward a little; consequently, the needles cannot be depended on to keep their proper position, especially with a tight stitch, which puts considerable work on the lander and on the driving needles. The requirements show that the lander should run as near as possible, without touching, to the leads or the cylinder (as the case may be), and as near as possible to the presser without touching it and allowance should be made for deflection of the driving needles inward and backward. The necessity for this allowance accounts for the popular rule to set the bur loosely, because if set tight, the displacement of the needles will still further tighten it. However, it is evident that if the bur is too loose, it will overreach so that the end of a blade will buck the oncoming needle. The point of contact is low on the shank of the needle where it cannot give very much, so the result is either bruising of both the needle and the end of the blade, bending outward of the needle, or breakage of the blade. The bruising causes tearing and cutting of the yarn, the bending outward of the needles destroys their alignment in a manner which is readily recognized, since needle displacement is generally inward and a broken lander blade generally causes a tuck stitch whenever that blade comes into action.

One of the most frequent sources of cutting is a rough lander blade. One reason for this is the facility with which it can be roughened, owing to its proximity to the presser and to the rigidity of the needle with which it interferes.

Sometimes a thread of waste winds around the lander stud and raises the bur so that it interferes with the presser. This causes a peculiar grinding sound when stationary pressers are used, but nicks and raises a round brass presser. The nicking of the brass presser is likely to be manifested by the appearance of tucks or cuts, whereas the raising of it prevents clearing the old stitches, and, consequently, leaves the yarn floated on the back of the fabric instead of being knit.

A loose lander stud will sometimes allow the bur to take a sudden dip into the leads, in which case a blade is likely to be broken out. Also a weak lander-bur support is likely to spring downward under the load at full speed, and to allow the blades to interfere with the leads or the cylinder according to whether leaded or trick needles are used.

CAST-OFF BUR

The cast-off bur raises the old loops from the swell of the beards, where the lander left them, up and off the heads of the needles, which is the stitch-finishing operation. This duty is much like that of the lander's, but it is favored by unrestricted space, which allows large diameter of bur, and affords the added advantage of more blades in mesh for secure driving. Still more, the cast-off blades may be set farther through the needles which also provides security. There is an offset to this in that the cast-off works near the tops of the needles where they are most pliable. But altogether the cast-off is considered the easiest bur to set; or, if it is well set, it is the least troublesome.

The common rule is to set the cast-off tight, since the backward bend of the needles in action loosens the cast-off less than the lander. The ideal position is supposed to be that which allows the entering blade to keep close to the forward needle, since this provides space for a backward pull under an overload, and allows the leaving blade to withdraw midway between the adjoining needles. Evidently to obtain this, the driving must be done against the blades which are well in mesh, which requires good design and correct adjustment. The absence of either of these puts so much work on the leaving needle that it snaps free with a force that vibrates it like a tuning fork. It is likely that this vibration shortens the life of the needle. Some knitters believe that in time it snaps the beards off. But at least, excessive pressure is likely to shear the yarn, especially at knots, by pinching the loop between the blade and the head of the needle.

The cast-off blades like those of the lander have a draw-cut action, so cutting is likely if they are sharp or nicked. Consequently, every precaution should be observed to get good blades with which to start. After that the principal cause of nicking is twisted beards. The cast-off blade, entering as it does from behind the needle, cannot get into the eye, neither can it get under the beard unless the latter is bent considerably to one side. But it is sometimes bent so by the sinker. The result is that the rising cast-off blade, entering between the beard and the shank, forces the beard off and nicks itself so that every time it touches the stitch it cuts some or all of the fibers.

The cast-off burs generally used in America have rounded points, which permit the blade to slip past a load-up, particularly if the needles spring outward to assist so doing. This method of casting off evidently lacks the positiveness of cast-off jacks, so the fabric from loop-wheel machines frequently lacks uniformity through this somewhat haphazard method of casting-off, unless other means are used for securing equal stitches. A rotary cast-off bur with a positive action simulating that of cast-off jacks is used to some extent, but it requires rather short needles in order to obtain a sufficiently positive drive to perform the harder work which it has to do.

The cast-off is supposed to be set sufficiently high to clear the stitches surely, and yet without cutting the stitch or causing one loop to steal from another. If it is too low, some stitches will not clear sufficiently, which causes very irregular fabric, or may not clear at all, which causes tucks. If the cast-off is too high, it will strain the stitches so that a cut will occur at a weak place in the yarn or at a rough place in the blade; or if not so high as to cut, the strain on the stitch may be sufficient to make the new stitch draw some yarn from the loop ahead, which stitch in its turn will do the same; but since the amount of yarn thus drawn is variable, the stitches must be irregular.

Spring-needle Dimensions and Data

1	2	3	4	5	6	7	8	9	10
Gauge	Dia.	Length	Beard	Cramp	Needle space, gross	Needle space, net	Sinker-blade thickness	Space between needle and blade	Yarn space (½ of 9)
5	.1200	2.30	.70	.060					
7	.0800	2.10	.70	.050					
8	.0570	2.00	.65	.040	.1971	.1401	.020	.1201	.0600
10	.0510	1.85	.55	.030	.1562	.1052	.020	.0852	.0426
12	.0475	1.70	.53	.027	.1290	.0815	.020	.0615	.0307
14	.0415	1.70	.51	.023	.1102	.0687	.020	.0487	.0243
16	.0390	1.57	.48	.020	.0961	.0571	.016	.0411	.0205
18	.0355	1.48	.40	.016	.0852	.0497	.016	.0337	.0168
20	.0315	1.48	.38	.016	.0766	.0451	.016	.0291	.0145
22	.0290	1.48	.36	.013	.0696	.0406	.010	.0306	.0153
24	.0280	1.45	.32	.012	.0636	.0356	.010	.0256	.0128
26	.0260	1.31	.32	.009	.0586	.0326	.010	.0226	.0113
28	.0260	1.40	.30	.006	.0544	.0284	.009	.0194	.0097
30	.0230	1.31	.25	.004	.0508	.0278	.009	.0188	.0094
32	.0220	1.28	....	.....	.0476	.0256			
34	.0220	.....	....	.....	.0447	.0227			
36	.0200	1.17	.24	.003	.0422	.0222	.006	.0162	.0081
38	.0190								
40	.0190								

This table is based on average needle dimensions from a prominent spring-needle manufacturer, and on average blade thickness of a prominent loop-wheel machine. Both the needle company and the machine company emphasize the quite well-known fact that there are but few if any recognized standards for needle and sinker design. Therefore, this table is not to be taken as final, but rather as an initial basis from actual practice, with the help of which more refined tables may be made after the principles of needle and sinker design are better understood.

Approximate Weight in Pounds per Thousand of Leaded Needles for Spring-needle Loop-wheel Machine

Gauge	Pounds	Gauge	Pounds	Gauge	Pounds
12	15.0	20	8.1	28	5.7
14	11.7	22	7.3	30	5.4
16	10.2	24	6.6	32	5.2
18	9.1	26	6.1	34	5.0

Spring-needle Loop-wheel Knitting

Trouble	Cause	Remedy
Small hole with single cut in yarn.	Rough or nicked blade is in lander or cast-off.	Polish or replace blade.
	Sinker bur is too tight or too loose, so that blade binds the yarn against the needle.	Readjust or replace sinker.
	Eyes of needles are too long or too low, so that the yarn cuts in the sinking of the stitch.	Shorten the beards or eyes, or use larger sinker.
	Eyes of needles are too shallow, so that the point of the beard is not covered.	Replace needles.
	Beards are turned to one side or the other.	Replace needles or repair the mold.
	Lander is set so tight or so loose that it cuts the stitch against needles.	Readjust or replace the lander.
	Lander blades cut the stitch against the presser.	Readjust the lander or presser, or both.
	Cast-off is so high as to break the stitch.	Depress the cast-off.
	Clearing bur cuts the stitch against the leads or cylinder.	Elevate clearing bur or move push down ahead.
	Push down is so far inward that the stitch is pulled tight on the needle and is cut during pushing down.	Move the push down out or reduce take-up tension.
A series of drop stitches without a break in the yarn.	Yarn drops down off the sinker. (This is characterized by a tight thread crossing the hole.)	Elevate the guide, put tension on the yarn, or use a blade with a more prominent nib.
	Yarn at the sinker bur runs up over the beards. (This is characterized by a loose thread crossing the hole.)	Lower the guide, or sinker, or shorten the beard.
	Yarn drops out from under the beards between the sinker and the presser. (Characterized same as No. 2.)	Cramp the needle beard, use the stationary presser extending from under the sinker to the lander; dampen the yarn.
	Push down rolls the stitches on the outside of beard. (Characterized same as No. 2.)	Move the push down back from the needles, increase the take-up tension or use a wire tension against the cloth ahead of the push down and above it.

Spring-needle Loop-wheel Knitting

Trouble	Cause	Remedy
Tears or long ragged holes or a series of them.	Lander is too high.	Lower the lander.
	Lander blades are too blunt.	Use a new lander.
	Take-up is slack.	Increase the take-up tension or use a tension wire on the cloth above and behind the push down.
	Heel of the push down is too low.	Elevate the push down.
	Push down bears on the lander.	Move push down forward.
	Push down bears on the leads or the cylinder.	Elevate the push down.
	Needles are rough or tarnished.	Polish by running with a strong yarn and a loose stitch.
Tucks in a vertical line.	The needle beard is low so that the yarn is split and part remains on the outside of the beard.	Replace the needle.
	The needle is bent inwardly so that it is not completely pressed.	Bend it outwardly.
	The needle is loose in the lead or trick.	Replace if leaded, or renew the leather if trick.
	The needle is weak, owing to deficient temper, so that it bends away from the presser.	Replace the needle.
	A mote or seed is lodged in the head of the needle, so that the stitch will not cast-off readily.	Remove the obstruction.
Single drop stitches.	The sinker bur is clogged with lint so that the beard is pressed down and the yarn cannot get under it. (If successive spaces are clogged a succession of drops will be caused.)	Clean sinker bur.
	The sinker bur is so tight that the blades brush a beard down so that the yarn cannot get in under it.	Readjust the sinker or use one that runs more freely.
	The yarn is dropping out from under beard after leaving sinker or running out of the yarn groove on the sinker bur.	See "Series of drop stitches without a break in the yarn."

Spring-needle Loop-wheel Knitting

Trouble	Cause	Remedy
Rows of tight stitches.	The guide is clogged with lint. This may make a number of courses of tight stitches before the yarn breaks or the lint pulls through and runs into the needles.	Clean the guide and polish the periphery of the hole or enlarge the hole.
	Pull from bobbin due to: Rough barrel.	Replace bobbin.
	Pull from bobbin due to: Coils pulled under others.	Use quicker traverse or more tension in winding.
	Pull from bobbin due to: Incorrect distance from thread eye.	Elevate or depress bobbin to point of freest delivery.
	Pull from bobbin due to: Bobbin not under eye.	Place bobbin so yarn delivery is uniform all around.
	Pull from cone due to: Wrong position.	See above.
	Pull from cone due to: Friction on side of cone.	Use cone with more taper, or increase speed of knitting machine.
	Pull from cone due to: Knot or seed on side of cone.	Remove obstruction or turn by hand until it is removed.
	Pull from cone due to: Underwinds.	Improve the winding.
	Sinker bur cramped so that the blades bind the needles and bend them inwardly so that full stitch is not taken.	Readjust bur or replace with one properly designed.
Beards of the needles broken off.	The stop motion claw may be so close to the needles that it catches a high beard.	Draw the claw back.
	The toe of the flat presser is so sharp that it gets in under a high beard.	Round the toe of the presser.
	The cast-off is so far through the needles that it pushes the stitch out against the beards and breaks them off.	Move the cast-off inwardly.
	The presser is set so hard that the beard is pressed down flat and breaks at the head or cramp.	Press lighter or farther toward the point of the beard.
	The guide is too close to the needles.	Move the guide out.
	The sinker bur backs out for a bunch and does not return fully to position.	Tighten the spring in the sinker tube.
	The guide strikes sinker causing it to over-reach.	Move the guide away, or if it is too flexible to retain its position against the tension of the yarn, use a heavier guide.

Spring-needle Loop-wheel Knitting

Trouble	Cause	Remedy
Needles breaking at the lead or trick.	The lander bur is over-reaching so that blades buck needles.	Set the lander to run tighter in the needles.
	The presser is set so deep as to bend needles too much.	Press lighter.
	The needles are too short. Occurs when yarn is heavy or wiry, and stitch is long as in knitting linen or ramie.	Use longer needles.
	The cast-off is set so tight as to snap the needles as they leave.	Set the cast-off looser.
Tucks made at random.	The round presser is nicked by bruise or by striking the lander blades so that it acts as a tuck presser.	Turn down the presser.
	A bent blade in the sinker is brushing down a needle beard occasionally so that the yarn comes up outside of the beard.	Replace the blade.
	The cast-off blade is broken or out so that the stitch is not cast off.	Insert a blade.

TUCK-STITCH FIGURES — LATCH-NEEDLE

The needles in latch-needle knitting machinery are operated by cams, and the angles of these cams cannot be so steep as to operate one needle at a time, for if they were so steep, then the butts would be sheared off. But to produce tuck figure designs it is desirable to be able to make any one needle tuck or knit. Consequently, some other device than the cam is needed to operate the needles. The most used device is a wheel which takes the place of the final rise on the raising cam. The first part of the raising cam, which brings the needles to the tuck position, is left just as in the ordinary machine. If the wheel had no cuts in its edge, the machine would knit plain fabric just as if the ordinary raising cam were used; for after the needle had been raised to the tucking position by the fixed cam, the butt would come to the flat upper face of the wheel and be raised farther so that the needle would knit, as the angle of the

Needles in Tompkin's Spring-needle Leaded Cylinders

Dia.	Gauge												
	12	14	16	18	20	22	24	26	28	30	32	34	36
9	218	256	294	331	369	406	444	481	519	556	594	632	669
10	243	285	326	368	410	451	493	535	577	618	660	702	743
11	267	313	359	405	451	497	543	589	635	680	726	772	818
12	291	342	392	442	492	542	592	642	693	742	798	843	892
13	306	370	424	479	533	587	641	696	750	804	858	913	967
14	340	399	457	516	574	632	691	749	808	866	924	983	1041
15	364	427	490	553	615	677	740	803	866	928	990	1053	1115
16	389	456	523	589	656	723	790	856	924	990	1056	1124	1190
17	413	484	555	626	697	768	839	910	981	1052	1122	1194	1264
18	437	513	588	663	738	813	888	963	1039	1113	1189	1264	1339
19	462	541	621	700	779	858	938	1017	1097	1175	1255	1335	1413
20	486	570	653	737	820	903	987	1071	1155	1237	1321	1405	1487
21	510	598	686	774	861	949	1037	1124	1212	1299	1387	1475	1562
22	535	627	719	811	902	994	1086	1178	1270	1361	1453	1545	1636
23	559	656	751	847	943	1039	1135	1231	1328	1423	1519	1616	1711
24	583	684	784	884	984	1084	1185	1285	1386	1485	1585	1686	1785
25	608	713	817	921	1025	1129	1234	1338	1443	1547	1651	1756	1895
26	632	741	849	958	1066	1175	1283	1392	1501	1608	1717	1826	1934
27	656	770	882	995	1107	1220	1333	1445	1559	1670	1783	1897	2008
28	681	798	915	1032	1148	1265	1382	1499	1617	1732	1849	1967	2083
29	705	827	948	1069	1189	1310	1432	1552	1674	1794	1915	2037	2157
30	729	855	980	1106	1230	1355	1481	1606	1732	1856	1981	2107	2231
31	754	884	1013	1142	1271	1401	1530	1660	1790	1918	2047	2178	2306
32	778	912	1046	1179	1312	1446	1580	1713	1848	1980	2113	2248	2380
33	802	941	1078	1216	1353	1491	1629	1767	1905	2042	2179	2318	2455

face of the wheel (not the edge) is just that of the higher part of the raising cam. But the object of the wheel is not to make all of the needles knit, but to make certain of them tuck This is accomplished by cutting grooves in the edge of the wheel, wide enough and far enough apart to let some needle butts enter. From this it follows that the wheel must revolve. In revolving it meshes with the butts just as a gear does with the teeth of another gear. The needles whose butts enter the spaces in the wheel are not raised above the tucking position, so they tuck; but the needle butts for which no spaces are provided ride up on the face of the wheel and are, consequently, raised so that these needles knit.

Suppose that one feed is used with a pattern wheel cut so as to catch every second butt in a space and the others on the face of the wheel. Then every needle which enters a space will tuck, and every one which does not will knit. If the number of needles in the cylinder is even, then the same needles will tuck every time around, and the machine will become loaded up; but if an odd number of needles is used, then the needles which tuck one time will clear the next, and so produce fabric containing diagonal tuck stitches. From this it is evident that the number of needles in the cylinder is determined to an extent by the arrangement of the cuts in the pattern wheel But if there are two feeds, then the second one may be provided with the regular cams and so clear all the tucks; or it may be provided with a pattern wheel so designed that each one will clear the tucks of the other. The number of feeds is not restricted to one or two, but may be any number which space will allow, and all or part of them may have pattern pressers according to the design to be made. The conditions to be met and ways to meet them are explained under the heading Figure Designing with Pattern Wheels.

Machines such as the one just described, that is, with an odd number of cylinder needles (no dial) and two feeds, each with a knit-one-tuck-one pattern, are used for making incandescent mantles. Each wale consists of two tuck stitches followed by two plain stitches.

VERTICAL PATTERNS IN LATCH-NEEDLE KNITTING

Vertical effects in the fabric are generally caused by differences in the needles. It is possible to obtain some vertical effects otherwise, as by an automatic striper changing every half-revolution of the machine, but very narrow effects could not be so obtained.

It happens sometimes on a two-feed machine that a needle becomes roughened so that it does not clear, i.e., tucks, at one feed, but knits under the extra pull of the second loop at the other feed. Suppose it is a cylinder needle. Then it makes a vertical stripe one wale in width but with only half as many courses per inch as the rest of the fabric, because the thread which was taken where the needle tucked is not drawn through into the face but lies back out of sight. Suppose this hidden thread is black and the other thread is white. Then the pattern is a white vertical stripe in a field of alternate black and white horizontal stripes one course in width.

Several facts may be noted from this illustration.

1. A vertical effect may be caused by making one wale different from another owing to a difference in its needle from the other's. Evidently these different needles might be spaced or grouped in different ways.

2. The yarn which is fed where a stitch is tucked is hidden, whereas the held loop is pulled through upon the face of the goods.

3. The number of courses in the tucked wale is $\frac{1}{2}$, $\frac{1}{3}$ or $\frac{1}{4}$ of those in the plain wales according as the needle clears at the second, third or fourth feed. For instance, on single tuck the needle tucks at the first feed and clears at the second feed, so its wale has only $\frac{1}{2}$ as many courses per inch as the plain rib fabric; and on double tuck the needle tucks at the first feed, then at the second and finally clears at the third, so its wale has $\frac{1}{3}$ the number of courses per inch as the plain rib fabric.

Now, if a needle can produce a different effect by accident, it can be intentionally made to produce a different effect. Two obvious methods of changing its action are (1) to unload it entirely by dropping its stitch, or (2) to load it up with one or more extra threads. The second method is the one involved in this discussion.

The loading up of any one needle independently of the others is considered to the best advantage on a two-feed machine. It is generally accomplished in one of two ways.

1. By the use of a long latch on the needle to be loaded.
2. By reduction of the travel of the needle to be loaded.

The No. 1 method may be used with a single cam race, whereas the No. 2 method requires more than one cam race.

Consider the No. 1 method used in an imaginary rib machine with ten needles and with two feeds, with black yarn at one feed, white yarn at the other feed and with long latches in four adjacent needles. The machine may have a dial or not. If it has a dial, the inside of the fabric will show black and white courses alternately. If it has no dial the alternate courses will still be black and white except that where the tucking occurs, the color which is kept out of the face will appear in the back. Set the raising cam at the black feed so that all of the latches clear, i.e., all knit, and set the raising cam at the white feed so that the four long latches do not clear, i.e., so they tuck. Then the six short latch needles will knit at each feed to make a gray field composed of alternate black and white courses, but the four long latch needles, instead of pulling the white yarn through upon the face of the goods, will merely hold it until the black feed is reached, when each will leave the white hidden by drawing another black loop through the black stitch it already has. The pattern will be a black vertical stripe of double length stitches, four wales in width, in a gray field composed of alternate black and white courses.

Now elevate the raising cam at the white feed so that the long latches are cleared there also. Then all of the needles knit alternate black and white courses, which terminate the black stripe. That is, the vertical effect produced by the long-latch needles may be stopped by raising them enough to clear their latches; and it may be started again by depressing the raising cam. Or the raising cam at the black feed might be depressed so that the long latches would be held there, in which case the pattern would be a white block of double length stitches, four wales in width, and still in the field of alternate black and white courses.

Summary — Long and Short Latches

With a machine having two feeds of different colors and needles with long and short latches, a vertical stripe on the long-latch needles may be:

(1) Made by not clearing the long latches at the feed whose color is to be hidden.

(2) Terminated by clearing the long latches at that feed.

(3) Reversed in color by not clearing the long latches at the other feed.

From No. 2 it is evident that both raising cams may be raised so that all of the needles knit plain fabric as though their latches were just alike. It also follows that one raising cam may be lowered so that all of the needles tuck at that feed (whether long latches are used or not), in which case all must knit at the other feed in order to clear the stitches; the result of which is that the color which is cleared conceals the other color throughout, and makes what is called the accordion stitch when a dial is used and all the dial needles knit.

One peculiarity should be noticed in reversing the color of the stripe by causing the long-latch needles to tuck at the reverse feed. Suppose the cams are reversed simultaneously (1) just after the long-latch needles have tucked and (2) just after they have cleared. In either case, since the cams are reversed, the needles with long latches must repeat at the next feed what they did at the last, i.e., in the first case must make a second tuck, or in the second case must clear a second time. In other words, it is impossible to make the change without knitting half a course at the new feed just as it was knit at the preceding feed, whether that was tucked or cleared. If, rather than to change the color of the stripe by a reversal of the cams, it is changed by a reversal of the yarns, as with automatic stripers, the half course of extra tucks or extra plain stitches will not have to be made.

Now go back to the imaginary two-feed machine with the four needles with long latches tucking at the white feed, thus knitting a black stripe, and the short-latch needles knitting an alternate black and white course field. Suppose that the lengths of the latches were instantly transposed, i.e., that the long latches became short, and vice versa. The stripe would then become alternate black and white courses, and the field would become black, i.e., the whole pattern would be exactly reversed, which was impossible before when only the stripe could be changed by making use of the difference in the lengths of the latches.

This complete reversal can be obtained in practice by the second method, that is by making the travel of some of the needles different from others with the use of a double cam race. There is the additional advantage that the alternate black and white field may be eliminated, when a dial is used, by tucking and clearing at alternate feeds instead of at one feed, so that the stripe may be black and the field white or vice versa. Otherwise, the same conditions hold as for long and short latches.

(1) The color fed where a latch is not cleared is hidden.

(2) A latch not cleared at one feed must clear at another.

(3) A vertical stripe on certain needles may be made, reversed, or terminated, respectively, by not clearing their latches at one feed, by not clearing at the other feed, by clearing at both feeds.

(4) If the pattern is reversed by a reversal of the cams, the needles with tucks add a tuck at the next feed and the needles which have just cleared, clear again at the next feed.

(5) A reversal of pattern by reversal of the yarn does not introduce the extra tucks or the extra plain stitches.

(6) Plain rib may be made by clearing all needles at both feeds or accordion (with use of a dial with all dial needles knitting), by clearing all needles at either feed and tucking at the other feed.

Diametral r.p.m., and Feet and Yards of Yarn Used per Minute per Feed by the Latch-needle Rib Machine

Dia. r.p.m.	Needle velocity per minute		Yarn velocity per minute (4 inches of needles to 1 foot of yarn)		Difference between velocity of yarn and needles, feet per minute
	Feet	Yards	Feet	Yards	
100	26.2	8.7	78.5	26.2	52.36
120	31.4	10.5	94.3	31.4	62.83
140	36.7	12.2	110.0	36.7	73.30
160	41.9	14.0	126.0	41.9	83.80
180	47.1	15.7	141.0	47.1	94.25
200	52.4	17.5	157.0	52.4	104.70
220	57.6	19.2	173.0	57.6	115.20
240	62.8	20.9	189.0	62.8	125.70
260	68.1	22.7	204.0	68.1	136.10
280	73.3	24.4	220.0	73.3	146.60
300	78.6	26.2	236.0	78.6	157.10
320	83.8	27.8	251.0	83.8	167.50
340	89.0	29.7	267.0	89.0	178.00
360	94.2	31.4	283.0	94.2	188.50
380	99.5	33.2	298.0	99.5	199.00
400	105.0	35.0	314.0	105.0	209.40
420	110.0	36.7	330.0	110.0	219.90
440	115.0	38.3	346.0	115.0	230.40
460	120.0	40.0	361.0	120.0	240.90
480	126.0	42.0	377.0	126.0	251.30
500	131.0	43.7	393.0	131.0	261.80
520	136.0	45.3	408.0	136.0	272.30
540	141.0	47.0	424.0	141.0	282.70
560	147.0	49.0	440.0	147.0	293.20
580	152.0	50.6	456.0	152.0	303.70
600	157.0	52.4	471.0	157.0	314.20
620	162.0	54.0	487.0	162.0	324.60
640	168.0	56.0	503.0	168.0	335.10
660	173.0	57.7	518.0	173.0	345.60
680	178.0	59.4	534.0	178.0	356.10
700	183.0	61.0	550.0	183.0	366.50
720	188.0	62.6	565.0	188.0	377.00
740	194.0	64.7	581.0	194.0	387.50
760	199.0	66.4	597.0	199.0	397.90
800	209.0	69.7	628.0	209.0	418.90
820	215.0	71.7	644.0	215.0	429.40
840	220.0	73.4	660.0	220.0	439.80
860	225.0	75.0	675.0	225.0	450.30
880	230.0	76.7	691.0	230.0	460.80
900	235.0	78.4	707.0	235.0	471.20

The average yarn velocity of circular loop-wheel knitting machinery is 86 per cent of the above for the same needle velocity.

NAMES OF CAMS

Cams are divided into two general classes: namely, working cams, which transmit the work of forming the stitch, or of similar operations; and guard cams, which keep the needles from traveling too far after leaving a working cam. In other words, the guard cams are those which combine with the working cams to close the cam races and so keep the needle butts in a restricted path. The usual working cams are the stitch cam, which propels the needle when it is drawing the stitch; the landing cam, which projects the needle slightly immediately after the stitch is drawn; and the raising cam, which projects the needle preparatory to drawing the stitch, and which generally contains two rises, one to open the latch and hold it open until the yarn carrier is reached, and the other to clear the latch where the yarn carrier will keep it from closing before the yarn gets under the hook. A switch cam is one which changes the path of the needle butts, much as a railroad switch changes the path of the train. Switch cams are generally a combination of working and guard cam, since it is desirable to control the travel of the butt especially in high-speed machines. There are exceptions to this, as in some automatic hosiery machines, in which guard cams are seldom used, since the friction of the needle in its slot and in the work is sufficient to keep it from traveling too far. Switch cams are of two general kinds, sliding and swinging, or wing cams.

ADJUSTING IN GENERAL

Remember that screws, etc., have to be proportioned according to their uses and that consequently the force applied to them should be limited according to their size. Use screw-drivers of the proper width and ground like screw-drivers instead of like chisels. Use wrenches with straight parallel jaws. Use judgment in forcing screws, especially hardened ones, since they are not easily removed if the heads are broken.

Always make a definite adjustment, such as a quarter turn, a half division, etc., and remember just what it was, so that it can be halved or doubled or retracted entirely according to the indications of the results. The habit of making only definite adjustments is especially desirable with knitting machinery in which the different parts are frequently duplicated many times, as in the feeds, of which 8, 12, 16, etc., may be used.

Make only one independent adjustment at a time. For instance, if the cylinder-stitch cam is elevated, which shortens the stitch, the dial stitch which is dependent on it may break unless the dial-stitch cam is brought outward. But do not bring out the dial-stitch cam and depress the dial at the same time, since if the result is unsatisfactory, it is difficult to tell which of the two changes should be rectified. A new engineer in a prominent knitting mill adjusted the whole engine in one evening and the mill had to close for three days while a crew from the shop lined it up again.

Tighten screws and nuts after temporary adjustment, since if something slips, more time may be lost in repairing damage than in loosening the screws or nuts for final adjustment.

After adjustment of any automatic change mechanism, turn the machine through the change by hand, since for many such adjustments there are positive limits which appear only during operation and if they are exceeded with the power on, damage is almost inevitable.

When dissembling any part of the machine, notice the order in which it comes apart, for use in reversing that order in reassembling. Corresponding parts are frequently marked to correspond, with numbers or prick punch marks. These should be followed carefully in reassembling. This is especially important in replacing the cross bar.

PUTTING NEEDLES INTO RIBBER

Nothing but the needles manipulates the yarn during the formation of the stitch, so it is essential that the needles be good. An absolutely perfect machine will not produce good results with poor needles; and since the needles are more readily changed than the machine, it is always well to look first to the needles in case of trouble. It is best to look the needles over before putting them in the machine, for even if imperfect needles are the only ones available, knowledge of their characteristics will help to locate trouble if any develops.

The slot for removal and replacement of cylinder needles is in the back cam casing, closed by a swing cover to keep dirt out of the cam race. To remove a needle, swing back the cover and bring the slot opposite the needle to be removed. With a needle held in one hand hook the head of the needle to be removed and draw it up until the butt is near the spring-band, draw the spring-band out with a coarse needle held in the other hand, and continue drawing the needle upward and out of the slot. Hold the new needle near the head, start the shank in the slot, pulling out the spring-band as before to clear the way for the butt, and press the needle down until it strikes the cam.

The slot for removal and replacement of dial needles is under and behind the oil hole in the cap. With a needle held in the hand, hook the head of the dial needle and draw it out. About four needles may be removed through this slot without change in the position of the machine. If it is desired to remove several needles at one place, a convenient way to move the cap the right distance is to count four needles passed by the heel of the yarn carrier. This relieves the operator from stooping to look under the cap.

Do not leave a needle part way in the slot. Put it all of the way in or take it out entirely, since if left otherwise, the power may be thrown on and the machine damaged.

Do not turn the machine during removal or insertion of a needle, as the needle may catch and necessitate the undesirability of turning the machine backward.

Make sure that the needles do not bind, especially when inserting a number. Just how snugly they may fit has to be learned by experience. As a rule they may be tighter in a ribber than in a body machine, since resistance in a ribber can be more readily detected through the hand wheel.

If the dial needles are snug, it is well to try each needle head first in its slot as the needle is likely to be widest through the rivet and binding in that location is not readily detected otherwise.

Do not wedge the slots apart until every other means to loosen the needle has been tried. The slots are cut with greater accuracy than can be obtained by manipulation, so as often as one is forced it follows that the original accuracy is proportionately impaired. If a needle sticks, it may be due to variation in the needle, in which case try another one and keep on until one is found which will fit; or the slot may contain some dirt which needs to be cleaned out, or may have a bur at its end, which bur should be removed.

If the needles fit tightly, it is well to oil them freely and run the machine without the work on it until they slide easily in the slots. It is always advisable to do this after the insertion of a new set of needles, since hooking on the cloth with a snug set of needles is not an easy operation, and if a load-up does occur, damage is very likely to result, since the double resistance is apt to be so great that an occasional butt will shear off rather than drive.

A muffled thump is indication that a butt has caught seriously or has been cut off. In the latter case the dial should be raised or the cam casings should be removed, according to the location of the broken needle, and all broken parts should be found and pieced together to make sure that every piece is removed.

When the cap is raised, the needles will remain in their proper position for replacement of the cap, but in removal of the cam casings, care should be taken either to leave the butts as they were in the cam race or to rearrange them so before replacement of the segments of the casing, otherwise the segments will not go down into place. The casing segments of a machine with many automatic changes are a little puzzling to replace until some familiarity with them is obtained, but they should never be forced. Careful examination will show how the needles should be arranged to permit replacement.

Yarn for Latch-needle Rib Machine

1	2	3	4	5	6	7
Cut	$(\text{Cut})^2$	$\frac{(\text{Cut})^2}{4}$	$\frac{(\text{Cut})^2}{5}$	$\frac{(\text{Cut})^2}{6}$	$\frac{(\text{Cut})^2}{7}$	$\frac{(\text{Cut})^2}{8}$
3	9	2.3	1.8	1.5	1.3	1.1
4	16	4.0	3.2	2.7	2.3	2.0
5	25	6.3	5.0	4.2	3.6	3.1
6	36	9.0	7.2	6.0	5.1	4.5
7	49	12.3	9.8	8.2	7.0	6.1
8	64	16.0	12.8	10.8	9.1	8.0
9	81	20.3	16.2	13.5	11.6	10.1
10	100	25.0	20.0	16.7	14.3	12.5
11	121	30.3	26.2	20.2	17.3	15.1
12	144	36.0	28.8	24.0	20.6	18.0
13	169	42.3	33.8	28.2	24.2	21.2
14	196	49.0	39.2	32.7	28.0	24.5

Column 5 shows the cotton number of yarn generally used for the corresponding cut, column 1.

Columns 3 and 4 show yarn numbers lighter than usual and columns 6 and 7 yarn numbers heavier than usual. The numbers shown in column 7 are considered the heavy limit for single thread on the ordinary latch-needle rib machine. However, multiple-thread combinations with a somewhat heavier equivalent may be used.

HOOKING FABRIC ON RIBBER

It is assumed that the machine is a single feeder properly adjusted and ready to run, except that the cloth is not on the needles.

See that all the latches are open.

Unless there is room enough between the cylinder and dial to reach a needle down through, elevate the dial to provide sufficient room.

Take a piece of fabric from a machine of about the same size, but loosely knit from soft yarn, trim square the end which will not ravel, pass it up through the cylinder, catch the edge with a needle in the hand, draw it up and hook it on the nearest cylinder needles. If the fabric used is too fine, or the stitch is too tight, the loops will not pass over the heads of the needles, or will break in so doing, which affords an insecure hold to start with. If the yarn of which the fabric is made is too strong, it will not break as it should when it gets caught under a hook, so that a severe pull, which may cause a butt to catch, is put on the needle.

The best place to start hooking-on is right behind the feed, where the needles are drawn back to clear the stitch, but in some cases there is sufficient room between the two sets of needles at other places around the cylinder.

If the cylinder is too small to admit the hand conveniently, the fabric may be pushed up on the end of a screw driver until a small section is caught, and then the fabric must be drawn gently downward.

With the dogless device the inside of the cylinder is perfectly free from obstructions, but on other machines the fabric must be worked between the dogs sometime during the hooking-on, depending on the place where the operation is started.

The amount of fabric hooked-on should be the least that will give a secure hold. If too much is hooked-on, the surplus should be trimmed off with shears, as otherwise it is likely to clog the needles before it gets down between them.

After the first section of the edge of the fabric is hooked, turn the machine ahead slightly, reach down with the hook, catch a following portion of the edge and hook it on, continuing thus until the cylinder needles begin to withdraw through the fabric. Thread the yarn through the stop motion, through the hole in the top of the stud, or through the guide in the dogless attachment, if one is used, and finally through the yarn carrier and under the hooks of the cylinder needles, making sure that the hooks catch it, or else the fabric will clear and leave a place that will have to be patched afterward.

The yarn used at the start should be strong and rather light and the stitch should not be tight, otherwise it will break or fail to clear readily.

After the fabric starts into the feed, keep it pulled down enough to make sure that the cylinder latches will clear it going up and that it will pull clear of the needles as they draw all the way back, yet not enough to break the stitches. It is well to notice the feed frequently, as it is important to form the stitches properly or they may all break away, and necessitate an entirely new start.

Continue the hooking-on as before, taking care not to hook on double thickness and not to catch the opposite side of the cloth, as double thickness will break or clog the needles, and catching the opposite side will leave insufficient cloth to go around and will not provide uniform tension, which is needed to begin with. When the starting place is reached, lap the fabric over itself two or three needles to make sure of a secure hold all around.

If the fabric fails to go around, or is doubled, or for any reason promises to clog the needles, it is better to break the yarn out and clear the needles by a revolution of the machine with tension on the cloth, since it is better to make a new start than to bruise and bend the needles by a bad start.

Sometimes the fabric may catch on the end of the center stem and seem to be short on that account. It may be freed by the hand reached up through the cylinder.

If the yarn breaks in drawing over the dial needle, the dial may be too high, in which case lower it, with caution not to get it so low as to obstruct raw edges of the fabric, or a possible load-up, which is likely to occur right after hooking on.

Watch the dial needles ahead of the feed and open any latches which may have closed.

If the hooking-on seems fairly secure, start the cloth in the take-up. But if it is not secure, it is well to use hand tension a little longer, since if the stitches start to break, the hand can let up quickly, whereas the take-up may pull the fabric entirely free before the tension can be released.

It is well to have the cloth in the take-up before the power is put on, since the take-up pull is much more dependable than the hand pull.

After the power is put on, watch all around the needle line for loose yarn and if any appears that does not quickly knit down, stop the machine, or the needles will become clogged, in which case hooks and latches get bent, latches get bruised by the carrier and butts get cut off. Pull the loose yarn clear of the needles, taking care not to injure the latter, and hook a small piece of cloth on the bare needles and keep hand tension on it until the hole mends; or if the space is not large, take out the dial needles there, in which case the cylinder needles will generally pick up, after which the dial needles may be replaced and the rib knitting will start at once.

For multiple-feed machines the operation is substantially the same, except that each feed must be threaded just before the fabric comes to it and all of the feeds should be watched to make sure that they are clearing the stitch properly until the raw edges are down out of the way, after which there is not much danger of trouble.

RIBBER TAKE-UP

The take-up is driven by a cotton band which may be adjusted when unhooked by twisting or untwisting according as it is to be tightened or loosened.

The stop-off chain connects the take-up with the knock-off handle, and when properly adjusted releases the power if the band becomes too loose or comes off. It does not release the power if the pulley, miter gears or collars become loosened, so they should be tightened occasionally.

The sheave-wheel shaft, worm, and miter gears should be kept well oiled, but the take-up rolls should not be oiled more than is necessary or the oil will run along them upon the fabric.

The lightest tension is obtained when the weight hanger-rod is at its greatest extension back of the take-up and all the weights are on it. Moving the rod inward and removing the weights increase the tension, after which further increase is made by reversal of the head of the rod to the front of the machine, addition of weights and increase in its adjustment outward.

To start the cloth between the rolls lift the worm to the top of its shaft and give it a partial turn which will keep it out of mesh. See that the fabric is not twisted; after which place the end between the rolls, turning the latter with the fingers until the end comes through on the lower side, then pull it up through the opening in the leg base, and keep pulling until the take-up stops rising. Give the worm a turn, so that it will drop into mesh, and release the fabric, replacing the end through the opening in the leg base.

To remove the cloth, take hold of it below the take-up and draw it up through the opening in the leg base until the take-up is lifted. This raises the worm to the top of its shaft. Keep the tension on the cloth and give the worm a part turn to hold it up out of mesh. The cloth may then be withdrawn from between the rolls and the take-up is ready to restart.

LOCATING SOURCES OF TROUBLE IN RIB KNITTING

One of the most frequent troubles is a vertical streak caused by a particular needle. If it is caused by a closed latch, a glance at the needles above the location of the streak will generally show it. If it is not found in this way, take out a dial needle where the trouble seems to be and run the fabric down below the head base. If the streak has continued, count the number of wales between it and the intentional drop-stitch streak, which is the number of cylinder needles between the removed dial needle and the defective needle. If the streak is intermittent, as is frequently the case with drop stitches, put the head of a needle, back downward, in the intentional drop-stitch streak and follow down until opposite the last defect; there count the number of needles between the two streaks and locate the defective needle as before.

If the trouble manifests itself in horizontal lines, i.e., along a particular course instead of a particular wale, the cause is at a feed instead of at a needle. Mark the yarn at any convenient feed with a black oil spot, run the spot below the head base and count the courses between the marked course and the one showing the defect. This number is the number of feeds between that at which the mark was made and the defective one. If the defective course is below the marked course, then the defective feed is ahead of the marked feed.

STITCH ADJUSTMENT

The stitch is important, not only because it is the essential factor next to the diameter of the yarn which decides the structural characteristics of the fabric, but because correct stitch adjustment is necessary for good results in the operation of the machine. By stitch is meant the length of yarn in the loop. It is necessary to distinguish stitch as applied to the loop from stitches per foot of yarn. When the stitches per foot are increased, the stitch or individual loop is shortened and vice versa. The stitch is determined first by the size of the yarn and thereafter by the requirements of weight, appearance, and feel of the fabric. To lengthen the stitch, that is, to increase the yarn in each stitch, is to lengthen the loop, and to make the fabric loose or sleazy, if the original stitch was normal; and to shorten the stitch, that is, to decrease the yarn in each stitch, is to shorten the loop, and to make the fabric heavy or boardy.

In regard to the running of the machine, too tight a stitch will tuck and load up, whereas too loose a stitch will drop off the needles or pull twits apart.

The commonest and easiest way of counting the stitch is to count the number of courses with a stitch glass. The counting should be done off the machine to eliminate as much as possible the disturbance due to the pull of the take-up, and when a close count is desired, it should always be counted in the same location around the cloth and away from the dog streaks. Counting by courses is a good way when the length of the fabric is important, as is the case generally with pattern fabric. It also eliminates differences due to such yarn characteristics as twist and harshness. But it is not reliable when the weight of the fabric is important.

The most direct method to adjust the stitch is by the number of stitches per foot of yarn. Get the stitches per foot by marking on the yarn two oil spots a foot apart, running them into the machine and counting the number of cylinder needles between the spots, remembering that a space also is to be counted at one end just as in counting a screw thread. Frequently, it is possible to find on the stop motion convenient measuring distances which are more than a foot in length and, consequently afford a more accurate result. For scientific purposes one whole turn of the cylinder is taken in order to eliminate the effect of untrueness in the cylinder and dial, but for commercial purposes one foot is generally a sufficient length. The stitches per foot of yarn are desirable for solution of the weight of the fabric per unit of area, square yard or square foot, for solution of the pounds production, and many other useful details.

To start the machine the first care should be to have the stitch sufficiently loose so that the machine will start well. After that it may be adjusted according to the requirements, whatever they may be, such as weight per yard, weight per dozen, appearance, or feel. These adjustments are generally made to a known number of courses or stitches per foot, or by trial, but the rules given elsewhere provide a much more comprehensive method.

There are three places in which the stitch may be adjusted. They are:

1. Cylinder stitch cam.
2. Dial stitch cam.
3. Dial.

The extent and frequency with which any one should be used depend on various considerations among which the following are important:

The dial cannot go lower than the position which surely lets the fabric (bunches included) pass between it and the cylinder. The height to which it may go is greater than the stitch will require.

The cylinder stitch must be long enough to enable the loop to clear the needles without tucking or breaking, and should not be so long as to pull the yarn apart at twits. The range of adjustment provided in the machine is greater than that generally allowed by the yarn.

The dial stitch must be long enough to clear itself surely, but is limited by the length of yarn between the dial needles and cylinder needles. In fact the dial cam stitch adjustment is the most limited one of the three; moreover, it can be no longer than is allowed by the cylinder stitch. So as a rule, the dial stitch is set to clear as surely as possible and close itself as much as possible without unduly straining the yarn. After that the changes are generally made on the cylinder or dial or both, except that to shorten much on the cylinder requires reduction in the dial stitch. To lengthen on the cylinder or to change the position of the dial up or down does not necessitate a change in the dial cam. Moreover, the cylinder cam does not need to be adjusted for change in the elevation of the dial.

Summary

The cylinder stitch cam must be set to draw enough yarn for both the cylinder and dial stitch.

The dial stitch cam must be set to draw enough to clear the old stitch surely, but not enough to break the new loop.

The dial must be far enough away from the cylinder to let the fabric pass through, but may be adjusted farther without necessitating change in either the cylinder or dial cams, until the yarn begins to break or unhook from the cylinder needles, but this is not likely to occur until the fabric is too loose to be useful.

The cylinder stitch is adjusted by means of what is called the index eccentric in the cam casing below the place where the cylinder needles draw the yarn down to form the loop. When the screw slot is horizontal and in its highest position, the cam is at its lowest position. Half a turn in either direction gives the entire range of adjustment. The change of adjustment is greatest when the slot is vertical and reduces to zero when the slot becomes horizontal.

The dial stitch is adjusted by means of an eccentric like the one in the cam casing on top of the dial cap right after the feed, or by a headless screw in the edge of the dial cap in the same location. Turn the screw clockwise to lengthen the dial stitch.

The dial adjustment is effected by means of the nut at the top of the dial stud.

The machines with dogs have the nut threaded on the stud so a right-hand turn of the nut elevates the dial, and a left-hand turn depresses it. The stud binding screw must be loosened before each adjustment and tightened after it. When lowering the dial, push the stud down into position after unscrewing the nut, as it will not always drop with its own weight.

The dogless machines have capstan nuts threaded on a washer instead of on the stud, so they are turned to the right to depress and to the left to elevate. Use a stiff rod that fits the holes well in order not to bruise them by the slipping out of a scant or flexible wire. Stud binding screws are not used with the dogless attachment, but it is generally necessary to push the stud down after the nut is turned to depress.

ADJUSTING THE YARN CARRIER

The adjustment of the carrier involves four considerations:

1. The heel of the carrier must come as near as possible to the closing cylinder latches without touching them.

2. The bottom of the carrier must come as near as possible to the dial needles without touching them.

3. The inside of the carrier must come as near as possible to the hooks of the cylinder needles without touching them, unless knots catch between the carrier and the cheek of the needle, in which case the carrier may be moved out a little, provided the hooks surely catch the yarn.

4. The toe of the carrier should be adjusted outward to the position in which it does the least damage to the latches, a position variously estimated from $\frac{1}{8}$ to $\frac{1}{4}$ inch away from the needles depending on the shape and size of the carrier.

When the carrier is so adjusted, the hooks of the cylinder needles should not be uncovered, cylinder latches should not close inside of the carrier or catch in the yarn hole, and dial latches should not close under the carrier or before the yarn is under the latch. If these troubles occur, then the shape of the carrier or the location of the hole should be changed to overcome them.

Judgment should be used in the second adjustment, especially with machines having dial wing cams, since the height of the dial needles changes according to whether the latches are open or shut, whether the needles are in or out, whether the cloth is on or off, and whether the stitch is loose or tight either owing to adjustment or to a load-up. The carrier should be adjusted to clear the needles under all these conditions.

RIB KNITTING

Trouble, Cause and Remedy; especially for Ribbers

It is assumed that the machines are not in bad order either from excessive use or misuse, and that they are equipped with stop motions. If the machines are in bad order, trouble may arise from so many sources that it is cheaper to have them repaired than to search in books for remedies. If stop motions are not used, the yarn and winding should be first class. These subjects are not treated here, since they have been considered in other books.

Rib Knitting

Trouble	Cause	Remedy
Stitch dropped from one dial needle, but yarn not cut.	Dial latch closing under yarn carrier.	Lower carrier.
	Dial latch closing near heel of yarn carrier.	Move carrier back as far as possible without interfering with cylinder latches as they close. Carry the yarn lower so that it prevents the closing of the latch. Adjust the cap forward so that the dial needles will not come out so far, unless this interferes with drawing the stitch over the rivet.
Stitch dropped from one cylinder needle, but yarn not cut.	Cylinder needles rising too soon after drawing stitch and so releasing it before the dial needles withdraw to keep the tension on it.	Grind cylinder landing cam so it raises the cylinder needles no faster than the dial needles withdraw. Adjust dial cap forward unless restricted by other requirements.
	Yarn not caught by cylinder needles.	Adjust guard so it will catch.
	Yarn twisting out of cylinder needle hook.	Put tension on yarn. Dampen yarn.
Dial stitch dropped and yarn cut.	Dial needle in too far when yarn is drawing, thus cutting it on sharp edges of saw cut in needle.	Adjust cap back so that yarn is drawn over rivet.
	Lint or a mote clogged in saw cut so that latch cuts itself out of stitch.	Clean out obstruction.
	Latch binding owing to needle being bent or otherwise damaged.	Replace needle.
	Latch closing on one side of hook so letting other side cut stitch.	Replace needle.
	Dial needle drawing in too far, thus cutting stitch on edge of sinker or breaking it.	Adjust dial-stitch cam outward.
	Stitch so tight that it fails to clear and breaks when needle comes out.	Loosen stitch. Use lighter yarn or coarser cut.

Rib Knitting

Trouble	Cause	Remedy
Cylinder stitch dropped and yarn cut.	Latch swinging to one side and catching on dial needle thus breaking out of the stitch. May result from saw cut being out of line with the butt, the latch being loose, the latch being bent, the needle too loose in the slot.	Replace needle.
	Latch closing on yarn carrier.	Adjust yarn carrier forward.
	Yarn cutting between cylinder and dial needle.	Adjust dial so that the two sets of needles will not interfere.
	Stitch so long that the needle breaks the yarn in drawing it.	Use yarn suitable to the stitch, or readjust latter.
Vertical line of big stitches.	Edge of spoon landing on hook thus preventing latches closing completely.	Replace needle.
Vertical line or lines of dial tucks.	Dial latches scored by yarn carrier (on machines with tucking or welting attachment).	Raise yarn carrier so that dial needle with closed latch will pass beneath under all conditions, and replace damaged needles.
Needles loading up all around.	Slack take-up. Due to (1) Insufficient weight.	Add front weight or adjust take-up weight-hanger-rod outward. Take off back weight or adjust weight-hanger-rod inward.
	(2) Inoperation of take-up stop motion.	Adjust stop-off chain-connecting take-up and knock-off handle so that power will knock off before take-up rests on leg base.
	(3) Take-up pulley, gear, or collar loose.	Tighten loose part.
	(4) Take-up gummed.	Clean and oil take-up.
	Cloth held between dial and cylinder.	Elevate dial.
	Yarn too heavy.	Use lighter yarn or coarser cut.
	Stitch too tight.	Loosen stitch.

Rib Knitting

Trouble	Cause	Remedy
Fabric pulling off needles.	Dial needles scored all around by low carrier, and cutting stitches.	Raise carrier and replace damaged needles.
	Stitch far too tight.	Loosen stitch.
	Take-up tension too severe.	Take off front weights or adjust weight-hanger-rod inward. Add back weights or adjust weight-hanger-rod outward.
One or more cylinder stitches dropped in line with dogs.	Dogs holding fabric back so that cylinder stitches unhook from cylinder needles.	Increase take-up tension. Grind landing cam down *if allowable.*
Cut, or drop, with a seed, knot, slub, or bunch in it.	The seed, knot, slub, or bunch.	Keep these obstructions out as much as possible, by adjustment of the stop motion and by keeping the machine free from collections of lint. See that the freest possible passage is allowed for those that do go into the machine. Knots and bunches may catch between the yarn carrier and the cheek of the cylinder needle, or the dial needle may be out of its mid-position between the cylinder needles, so that the obstruction is held between cylinder and dial needle.
Press off without stop motion tripping.	Yarn parting owing to a pull between the needles and the sweep wire. (1) An eye clogged with lint owing to roughness, to being too long, to being too small	Modify eye. Use porcelain eye.
	(2) knot catching on sharp edge of eye.	Round edge. Use porcelain eye.
	(3) knot catching between yarn carrier and cheek of needle.	Move carrier out, if yarn is not likely to drop. Drill yarn hole higher.
	Lint holding feeler finger.	Clean stop motion regularly.
	Stop motions improperly threaded.	Use caution in threading.

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
2	5.317	3.761	4.137	4.514	4.890	5.266	5.642	6.018	6.394	6.770	7.146	7.522	7.899	8.275	8.651	9.028
¼	6.103	3.277	3.605	3.933	4.260	4.588	4.916	5.243	5.571	5.899	6.226	6.554	6.882	7.210	7.538	7.865
½	6.888	2.904	3.194	3.484	3.775	4.065	4.355	4.646	4.936	5.226	5.517	5.807	6.098	6.388	6.678	6.969
¾	7.674	2.606	2.867	3.128	3.388	3.649	3.909	4.170	4.431	4.691	4.952	5.212	5.473	5.734	5.994	6.255
3	8.460	2.364	2.600	2.837	3.073	3.310	3.546	3.783	4.019	4.255	4.492	4.728	4.965	5.201	5.437	5.674
¼	9.244	2.164	2.380	2.596	2.813	3.029	3.245	3.462	3.678	3.894	4.111	4.327	4.544	4.760	4.976	5.192
½	10.030	.....	2.193	2.393	2.592	2.792	2.991	3.190	3.390	3.589	3.789	3.988	4.187	4.387	4.586	4.786
¾	10.815	.....	2.034	2.219	2.404	2.589	2.774	2.959	3.144	3.329	3.514	3.698	3.883	4.068	4.253	4.438
4	11.600	.....	.....	2.069	2.241	2.414	2.586	2.758	2.931	3.103	3.275	3.448	3.621	3.793	3.965	4.138
¼	12.386	.....	.....	.....	2.099	2.260	2.422	2.583	2.745	2.906	3.068	3.229	3.391	3.552	3.713	3.875
½	13.171	.....	.....	.....	.....	2.126	2.277	2.429	2.581	2.733	2.885	3.037	3.189	3.340	3.492	3.644
¾	13.957	.....	.....	.....	.....	.....	2.149	2.293	2.436	2.579	2.722	2.866	3.009	3.152	3.295	3.439
5	14.742	.....	.....	.....	.....	.....	.....	2.170	2.306	2.442	2.578	2.713	2.849	2.984	3.120	3.256
¼	15.528	.....	.....	.....	.....	.....	.....	2.060	2.189	2.318	2.447	2.576	2.705	2.834	2.975	3.091
½	16.313	.....	.....	.....	.....	.....	.....	.....	2.084	2.207	2.329	2.452	2.575	2.697	2.820	2.942
¾	17.100	.....	.....	.....	.....	.....	.....	.....	.....	2.105	2.222	2.339	2.456	2.573	2.690	2.807
6	17.883	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.125	2.237	2.348	2.460	2.572	2.684
¼	18.670	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.142	2.250	2.357	2.464	2.571
½	19.455	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.056	2.159	2.261	2.364	2.467
¾	20.240	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.075	2.174	2.273	.371

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78
2	5.317	9.403	9.780	10.160	10.530	10.910	11.280	11.660	12.040	12.410	12.790	13.160	13.540	13.920	14.290	.....
¼	6.103	8.193	8.520	8.848	9.176	9.504	9.832	10.160	10.490	10.810	11.140	11.470	11.800	12.130	12.450	12.780
½	6.888	7.259	7.550	7.840	8.130	8.420	8.711	9.002	9.292	9.582	9.872	10.160	10.450	10.740	11.030	11.320
¾	7.674	6.516	6.776	7.036	7.298	7.558	7.819	8.080	8.340	8.601	8.862	9.122	9.382	9.644	9.904	10.160
3	8.460	5.910	6.148	6.383	6.620	6.856	7.092	7.328	7.565	7.802	8.038	8.274	8.510	8.747	8.983	9.220
¼	9.244	5.409	5.625	5.841	6.058	6.274	6.491	6.707	6.923	7.140	7.356	7.572	7.789	8.005	8.221	8.438
½	10.030	4.985	5.184	5.384	5.583	5.782	5.982	6.182	6.381	6.580	6.780	6.979	7.178	7.378	7.577	7.777
¾	10.815	4.623	4.808	4.993	5.178	5.363	5.548	5.732	5.917	6.102	6.287	6.472	6.657	6.842	7.027	7.212
4	11.600	4.310	4.482	4.655	4.827	5.000	5.172	5.344	5.517	5.689	5.861	6.034	6.206	6.379	6.551	6.724
¼	12.386	4.037	4.198	4.359	4.521	4.682	4.844	5.005	5.166	5.328	5.490	5.651	5.812	5.974	6.136	6.297
½	13.171	3.796	3.948	4.100	4.251	4.403	4.555	4.707	4.859	5.010	5.162	5.314	5.466	5.618	5.770	5.922
¾	13.957	3.582	3.725	3.869	4.012	4.155	4.298	4.442	4.585	4.728	4.872	5.015	5.158	5.302	5.445	5.588
5	14.742	3.391	3.527	3.663	3.798	3.934	4.070	4.205	4.341	4.477	4.612	4.748	4.884	5.020	5.155	5.290
¼	15.528	3.220	3.348	3.477	3.606	3.735	3.864	3.992	4.121	4.250	4.379	4.508	4.636	4.765	4.894	5.023
½	16.313	3.065	3.187	3.310	3.433	3.555	3.678	3.800	3.923	4.045	4.168	4.291	4.413	4.536	4.658	4.781
¾	17.100	2.924	3.041	3.158	3.275	3.392	3.509	3.626	3.742	3.860	3.976	4.094	4.210	4.327	4.444	4.561
6	17.883	2.796	2.908	3.019	3.131	3.243	3.355	3.467	3.579	3.690	3.802	3.914	4.026	4.138	4.250	4.362
¼	18.670	2.678	2.785	2.892	2.999	3.106	3.214	3.320	3.428	3.535	3.642	3.749	3.856	3.963	4.070	4.177
½	19.455	2.570	2.673	2.775	2.878	2.981	3.084	3.187	3.289	3.392	3.495	3.598	3.700	3.803	3.906	4.009
¾	20.240	2.470	2.569	2.668	2.767	2.866	2.964	3.063	3.162	3.261	3.360	3.459	3.557	3.656	3.755	3.854

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108
2	5.317	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¼	6.103	13.110	13.440	13.760	14.090	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
½	6.888	11.610	11.900	12.200	12.490	12.790	13.070	13.360	13.650	13.940	14.230	.....	.....	.....	.....	.....
¾	7.674	10.420	10.690	10.950	11.210	11.470	11.730	11.990	12.250	12.510	12.770	13.030	13.290	13.550	13.810	14.070
3	8.460	9.456	9.693	9.930	10.170	10.400	10.640	10.870	11.110	11.350	11.560	11.820	12.060	12.290	12.530	12.770
¼	9.244	8.654	8.870	9.088	9.303	9.520	9.736	9.952	10.170	10.380	10.600	10.820	11.030	11.250	11.470	11.680
½	10.030	7.976	8.176	8.375	8.574	8.774	8.973	9.173	9.372	9.572	9.771	9.970	10.170	10.370	10.570	10.770
¾	10.815	7.397	7.582	7.767	7.952	8.137	8.321	8.506	8.692	8.876	9.061	9.246	9.431	9.616	9.802	9.986
4	11.600	6.896	7.068	7.241	7.413	7.586	7.758	7.930	8.104	8.275	8.448	8.620	8.793	8.965	9.138	9.310
¼	12.386	6.458	6.620	6.782	6.943	7.104	7.266	7.427	7.589	7.750	7.912	8.073	8.235	8.396	8.558	8.719
½	13.171	6.074	6.225	6.377	6.529	6.681	6.832	6.984	7.136	7.288	7.440	7.592	7.744	7.896	8.048	8.200
¾	13.957	5.732	5.874	6.018	6.162	6.305	6.448	6.591	6.735	6.878	7.021	7.164	7.308	7.451	7.595	7.738
5	14.742	5.426	5.562	5.698	5.833	5.969	6.105	6.240	6.376	6.511	6.647	6.783	6.919	7.054	7.190	7.326
¼	15.528	5.152	5.280	5.409	5.538	5.667	5.796	5.924	6.053	6.182	6.311	6.440	6.568	6.697	6.826	6.955
½	16.313	4.904	5.026	5.149	5.271	5.394	5.516	5.640	5.762	5.884	6.007	6.130	6.252	6.375	6.498	6.620
¾	17.100	4.678	4.795	4.912	5.029	5.146	5.261	5.380	5.497	5.614	5.731	5.848	5.965	6.082	6.199	6.316
6	17.883	4.473	4.585	4.697	4.809	4.921	5.032	5.144	5.256	5.368	5.480	5.592	5.704	5.815	5.927	6.039
¼	18.670	4.285	4.392	4.499	4.606	4.713	4.820	4.928	5.035	5.142	5.249	5.356	5.463	5.570	5.678	5.785
½	19.455	4.112	4.214	4.318	4.420	4.523	4.626	4.728	4.832	4.934	5.037	5.140	5.243	5.346	5.448	5.551
¾	20.240	3.952	4.051	4.150	4.249	4.348	4.447	4.545	4.644	4.743	4.842	4.941	5.040	5.138	5.237	5.336

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	110	112	114	116	118	120	122	124	126	128	130	132	134	136	138
2	5.317	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
$\frac{1}{4}$	6.103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
$\frac{1}{2}$	6.888	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
$\frac{3}{4}$	7.674	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	8.460	13.000	13.240	13.470	13.710	13.950	14.180	.....	.....	.....	.....	.....	.....	.....	.....	.....
$\frac{1}{4}$	9.244	11.900	12.120	12.330	12.550	12.770	12.980	13.200	13.410	13.630	13.850	14.060	.....	.....	.....	.....
$\frac{1}{2}$	10.030	10.970	11.170	11.370	11.570	11.760	11.960	12.160	12.360	12.560	12.760	12.960	13.160	13.360	13.560	13.760
$\frac{3}{4}$	10.815	10.170	10.360	10.540	10.730	10.910	11.100	11.280	11.470	11.650	11.830	12.020	12.200	12.390	12.570	12.760
4	11.600	9.483	9.655	9.828	10.000	10.170	10.340	10.520	10.690	10.860	11.030	11.210	11.380	11.550	11.720	11.900
$\frac{1}{4}$	12.386	8.881	9.042	9.203	9.365	9.527	9.688	9.866	10.010	10.170	10.330	10.490	10.660	10.820	10.980	11.140
$\frac{1}{2}$	13.171	8.351	8.503	8.655	8.807	8.959	9.110	9.262	9.414	9.566	9.718	9.870	10.020	10.170	10.320	10.480
$\frac{3}{4}$	13.957	7.881	8.024	8.168	8.311	8.454	8.598	8.741	8.884	9.028	9.171	9.314	9.457	9.601	9.744	9.888
5	14.742	7.462	7.598	7.733	7.868	8.004	8.140	8.275	8.411	8.547	8.683	8.818	8.954	9.090	9.225	9.361
$\frac{1}{4}$	15.528	7.084	7.212	7.341	7.470	7.599	7.728	7.856	7.985	8.114	8.242	8.371	8.500	8.630	8.758	8.886
$\frac{1}{2}$	16.313	6.743	6.866	6.988	7.111	7.234	7.356	7.478	7.601	7.724	7.846	7.969	8.092	8.214	8.337	8.460
$\frac{3}{4}$	17.100	6.433	6.550	6.666	6.784	6.901	7.018	7.135	7.252	7.368	7.486	7.603	7.720	7.836	7.954	8.071
6	17.883	6.151	6.263	6.375	3.487	6.599	6.710	6.822	6.934	7.046	7.158	7.270	7.381	7.493	7.605	7.717
$\frac{1}{4}$	18.670	5.892	5.999	6.106	6.214	6.320	6.428	6.534	6.642	6.749	6.856	6.963	7.070	7.177	7.285	7.391
$\frac{1}{2}$	19.455	5.654	5.757	5.860	5.962	6.066	6.168	6.270	6.374	6.476	6.580	6.682	6.785	6.888	6.990	7.093
$\frac{3}{4}$	20.240	5.435	5.534	5.632	5.732	5.830	5.929	6.028	6.127	6.226	6.324	6.423	6.522	6.620	6.720	6.818

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168
2	5.317	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¼	6.103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
½	6.888	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¾	7.674	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	8.460	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¼	9.244	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
½	10.030	13.960	14.160	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¾	10.815	12.940	13.130	13.310	13.500	13.680	13.870	14.050	.....	.....	.....	.....	.....	.....	.....	.....
4	11.600	12.070	12.240	12.410	12.590	12.760	12.930	13.100	13.270	13.450	13.620	13.790	13.960	14.140	.....	.....
¼	12.386	11.300	10.710	11.620	11.790	11.950	12.110	12.270	12.430	12.590	12.760	12.920	13.080	13.240	13.400	13.560
½	13.171	10.630	10.780	10.930	11.080	11.240	11.390	11.540	11.690	11.840	12.000	12.150	12.300	12.450	12.600	12.750
¾	13.957	10.030	10.170	10.320	10.460	10.600	10.750	10.890	11.030	11.180	11.320	11.460	11.610	11.750	11.890	12.040
5	14.742	9.496	9.632	9.768	9.904	10.040	10.170	10.310	10.450	10.580	10.720	10.850	10.990	11.120	11.260	11.400
¼	15.528	9.016	9.144	9.273	9.402	9.530	9.660	9.788	9.917	10.050	10.170	10.300	10.430	10.560	10.690	10.820
½	16.313	8.582	8.705	8.827	8.950	9.072	9.195	9.318	9.440	9.563	9.686	9.808	9.930	10.050	10.180	10.300
¾	17.100	8.188	8.304	8.421	8.538	8.655	8.772	8.889	9.006	9.123	9.240	9.356	9.474	9.591	9.708	9.824
6	17.883	7.829	7.940	8.052	8.108	8.276	8.388	8.500	8.612	8.724	8.835	8.947	9.059	9.171	9.283	9.394
¼	18.670	7.499	7.606	7.713	7.820	7.927	8.034	8.142	8.248	8.355	8.463	8.570	8.677	8.784	8.891	8.998
½	19.455	7.196	7.299	7.402	7.504	7.608	7.710	7.813	7.916	8.018	8.122	6.224	8.327	8.430	8.533	8.636
¾	20.240	6.917	7.016	7.115	7.214	7.312	7.411	7.510	7.609	7.708	7.807	7.905	8.004	8.103	8.202	8.300

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198
2	5.317	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¼	6.103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
½	6.888	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¾	7.674	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	8.460	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¼	9.244	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
½	10.030	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¾	10.815	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	11.600	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
¼	12.386	13.720	13.890	14.050	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
½	13.171	12.910	13.060	13.210	13.360	13.510	13.660	13.820	13.970	14.120	.....	.....	.....	.....	.....	.....
¾	13.957	12.180	12.320	12.470	12.610	12.750	12.900	13.040	13.180	13.330	13.470	13.610	13.760	13.900	14.040	.....
5	14.742	11.530	11.670	11.800	11.940	12.070	12.210	12.340	12.480	12.620	12.750	12.890	13.020	13.160	13.290	13.430
¼	15.528	10.950	11.080	11.200	11.330	11.460	11.590	11.720	11.850	11.980	12.110	12.230	12.360	12.490	12.620	12.750
½	16.313	10.420	10.540	10.670	10.790	10.910	11.030	11.160	11.280	11.400	11.520	11.650	11.770	11.890	12.010	12.140
¾	17.100	9.942	10.060	10.180	10.290	10.410	10.530	10.640	10.760	10.880	10.990	11.110	11.230	11.340	11.460	11.580
6	17.883	9.506	9.618	9.730	9.842	9.953	10.070	10.180	10.290	10.400	10.510	10.620	10.740	10.850	10.960	11.070
¼	18.670	9.106	9.213	9.320	9.427	9.534	9.641	9.748	9.855	9.962	10.070	10.180	10.280	10.390	10.500	10.600
½	19.455	8.738	8.841	8.944	9.047	9.150	9.252	9.354	9.457	9.560	9.664	9.766	9.869	9.972	10.070	10.180
¾	20.240	8.400	8.498	8.597	8.696	8.794	8.893	8.992	9.091	9.190	9.289	9.387	9.486	9.586	9.684	9.783

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228
2	5.317	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/4	6.103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/2	6.888	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3/4	7.674	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	8.460	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/4	9.244	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/2	10.030	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3/4	10.815	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	11.600	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/4	12.386	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/2	13.171	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3/4	13.957	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	14.742	13.570	13.700	13.84	13.97	14.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/4	15.528	12.880	13.010	13.14	13.26	13.39	13.52	13.65	13.78	13.91	14.04	.....	.....	.....	.....	.....
1/2	16.313	12.260	12.380	12.50	12.63	12.75	12.87	13.00	13.12	13.24	13.36	13.49	13.61	13.73	13.85	13.98
3/4	17.100	11.700	11.810	11.93	12.05	12.16	12.28	12.40	12.51	12.63	12.75	12.86	12.98	13.10	13.22	13.33
6	17.883	11.180	11.300	11.41	11.52	11.63	11.74	11.85	11.97	12.08	12.19	12.30	12.41	12.53	12.64	12.75
1/4	18.670	10.710	10.820	10.93	11.03	11.40	11.25	11.35	11.46	11.57	11.68	11.78	11.89	12.00	12.10	12.21
1/2	19.455	10.280	10.380	10.48	10.59	10.69	10.79	10.90	11.00	11.10	11.20	11.31	11.41	11.51	11.62	11.72
3/4	20.240	9.882	9.980	10.08	10.18	10.28	10.37	10.47	10.57	10.67	10.77	10.87	10.97	11.07	11.17	11.26

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	230	232	234	236	238	240	242	244	246	248	250	252	254	256	258
2	5.317	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/4	6.103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/2	6.888	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3/4	7.674	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	8.460	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/4	9.244	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/2	10.030	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3/4	10.815	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	11.600	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/4	12.386	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/2	13.171	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3/4	13.957	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	14.742	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/4	15.528	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/2	16.313	14.10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3/4	17.100	13.45	13.57	13.68	13.80	13.92	14.03	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	17.883	12.86	12.97	13.08	13.20	13.31	13.42	13.53	13.64	13.76	13.87	13.98	14.09	.....	.....	.....
1/4	18.670	12.32	12.43	12.53	12.64	12.75	12.85	12.96	13.07	13.18	13.28	13.39	13.50	13.60	13.71	13.82
1/2	19.455	11.82	11.92	12.03	12.13	12.23	12.34	12.44	12.54	12.64	12.75	12.85	12.95	13.05	13.16	13.26
3/4	20.240	11.36	11.46	11.56	11.66	11.76	11.86	11.96	12.05	12.15	12.25	12.35	12.45	12.55	12.65	12.75

Needles per Inch for Different Diameters and Numbers of Cylinder Slots

(The nominal diameter is that of the cam surface of the cylinder. The diameter from back to back of needles is .3075 less than the nominal diameter.)

Nominal dia.	Circum.	260	262	264	266	268	270	272	274	276	278	280	282	284
2	5.317	......	......	......	......	......	......	......	......	......	......	......	......	......
¼	6.103	......	......	......	......	......	......	......	......	......	......	......	......	......
½	6.888	......	......	......	......	......	......	......	......	......	......	......	......	......
¾	7.674	......	......	......	......	......	......	......	......	......	......	......	......	......
3	8.460	......	......	......	......	......	......	......	......	......	......	......	......	......
¼	9.244	......	......	......	......	......	......	......	......	......	......	......	......	......
½	10.030	......	......	......	......	......	......	......	......	......	......	......	......	......
¾	10.815	......	......	......	......	......	......	......	......	......	......	......	......	......
4	11.600	......	......	......	......	......	......	......	......	......	......	......	......	......
¼	12.386	......	......	......	......	......	......	......	......	......	......	......	......	......
½	13.171	......	......	......	......	......	......	......	......	......	......	......	......	......
¾	13.957	......	......	......	......	......	......	......	......	......	......	......	......	......
5	14.742	......	......	......	......	......	......	......	......	......	......	......	......	......
¼	15.528	......	......	......	......	......	......	......	......	......	......	......	......	......
½	16.313	......	......	......	......	......	......	......	......	......	......	......	......	......
¾	17.100	......	......	......	......	......	......	......	......	......	......	......	......	......
6	17.883	......	......	......	......	......	......	......	......	......	......	......	......	......
¼	18.670	13.93	14.03	......	......	......	......	......	......	......	......	......	......	......
½	19.455	13.36	13.47	13.57	13.67	13.77	13.88	13.98	14.08	......	......	......	......	......
¾	20.240	12.85	12.94	13.04	13.14	13.24	13.34	13.44	13.54	13.64	13.73	13.83	13.93	14.03

Diameter of Wildman Ribbers from Back to Back of Cylinder Needles

Nominal diameter	Actual diameter			Nominal diameter	Proportion of nominal diameter		
	Gauge				Gauge		
	18	24–30–36	48		18	24–30–36	48
2	1.68	1.69	1.70	2	.839	.846	.851
$2\frac{1}{4}$	1.93	1.94	1.95	$2\frac{1}{4}$	.856	.863	.868
$2\frac{1}{2}$	2.18	2.19	2.20	$2\frac{1}{2}$	.871	.877	.881
$2\frac{3}{4}$	2.43	2.44	2.45	$2\frac{3}{4}$	.883	.888	.892
3	2.68	2.69	2.70	3	.893	.897	.901
$3\frac{1}{4}$	2.93	2.94	2.95	$3\frac{1}{4}$	.901	.905	.908
$3\frac{1}{2}$	3.18	3.19	3.20	$3\frac{1}{2}$	.907	.912	.915
$3\frac{3}{4}$	3.43	3.44	3.45	$3\frac{3}{4}$	.914	.918	.921
4	3.68	3.69	3.70	4	.919	.923	.926
$4\frac{1}{4}$	3.93	3.94	3.95	$4\frac{1}{4}$	.925	.928	.930
$4\frac{1}{2}$	4.18	4.19	4.20	$4\frac{1}{2}$	.930	.932	.934
$4\frac{3}{4}$	4.43	4.44	4.45	$4\frac{3}{4}$	.933	.935	.937
5	4.68	4.69	4.70	5	.936	.939	.941
$5\frac{1}{4}$	4.93	4.94	4.95	$5\frac{1}{4}$	.940	.941	.943
$5\frac{1}{2}$	5.18	5.19	5.20	$5\frac{1}{2}$	.942	.944	.946
$5\frac{3}{4}$	5.43	5.44	5.45	$5\frac{3}{4}$	.945	.947	.948
6	5.68	5.69	5.70	6	.947	.949	.950
$6\frac{1}{4}$	5.93	5.94	5.95	$6\frac{1}{4}$	.950	.951	.952
$6\frac{1}{2}$	6.18	6.19	6.20	$6\frac{1}{2}$	.951	.953	.954
$6\frac{3}{4}$	6.43	6.44	6.45	$6\frac{3}{4}$	.952	.954	.956

Circumference of Wildman Ribbers at Back of Needles

Nominal diameter	Gauge			Nominal diameter	Gauge		
	18	24–30–36	48		18	24–30–36	48
2	5.273	5.317	5.349	$4\frac{1}{2}$	13.127	13.171	13.202
$2\frac{1}{4}$	6.059	6.103	6.134	$4\frac{3}{4}$	13.913	13.957	13.988
$2\frac{1}{2}$	6.844	6.888	6.920	5	14.698	14.742	14.773
$2\frac{3}{4}$	7.630	7.674	7.706	$5\frac{1}{4}$	15.482	15.528	15.559
3	8.415	8.460	8.491	$5\frac{1}{2}$	16.272	16.313	16.344
$3\frac{1}{4}$	9.200	9.244	9.276	$5\frac{3}{4}$	17.054	17.100	17.130
$3\frac{1}{2}$	9.986	10.030	10.062	6	17.841	17.883	17.915
$3\frac{3}{4}$	10.771	10.815	10.846	$6\frac{1}{4}$	18.627	18.670	18.702
4	11.557	11.600	11.631	$6\frac{1}{2}$	19.410	19.455	19.487
$4\frac{1}{4}$	12.341	12.386	12.417	$6\frac{3}{4}$	20.197	20.240	20.272

Performance of a Latch-needle Rib Body Machine

Details. Dia. = 20 inches; Feeds = 8; Yarn = 10.65 $\left(\text{from yarn} = \frac{(\text{Cut})^2}{6}\right)$; Stitch = 32 needles (cyl.); r.p.m. = 35; Cut = 8; Actual hours per day = 9

	Minute	Hour	Day	Week	Month	Year
Production, pounds	.162037	9.7222	87.5	525.0	2,187.5	26,250
Yarn, miles consumed	....	50.0000	450.00	2,700.0	11,250.0	135,000
Stitches, total	280,000.000000	16,800,000.0000	151,200,000.00	907,200,000.0	3,780,000,000.0	45,360,000,000
Stitches per needle	280.000000	16,800.0000	151,200.00	907,200.0	3,780,000.0	45,360,000
Vertical travel per needle, feet	40.000000	2,400.0000	21,600.00	129,600.0	540,000.0	6,480,000
Vertical travel per needle, miles	....	.4500	4.09	24.5	102.0	1,227
Circular travel, miles	....	2.0800	18.75	112.5	469.0	5,625
Reciprocations per needle (single)	560.000000	33,600.0000	302,400.00	1,814,400.0	7,560,000.0	90,720,000
Square yards knit	.300000	18.0000	162.00	972.0	4,050.0	48,600

Table of Maximum and Minimum Stitches

Yarn No.	$\sqrt{No.}$	Least number of stitches per foot of yarn for stable fabric	Greatest number of stitches per foot of yarn	Yarn No.	$\sqrt{No.}$	Least number of stitches per foot of yarn for stable fabric	Greatest number of stitches per foot of yarn
5	2.2361	15.25	29.74	23	4.7958	32.70	63.79
6	2.4495	16.70	32.59	24	4.8990	33.39	65.16
7	2.6458	18.04	35.19	25	5.0000	34.09	66.50
8	2.8284	19.28	37.62	26	5.0990	34.76	67.82
9	3.0000	20.45	39.90	27	5.1962	35.46	69.12
10	3.1623	21.56	42.06	28	5.2915	36.09	70.38
11	3.3166	22.61	44.11	29	5.3852	36.72	71.62
12	3.4641	23.62	46.07	30	5.4772	37.34	72.86
13	3.6056	24.58	47.96	31	5.5678	37.96	74.06
14	3.7417	25.51	49.77	32	5.6569	38.57	75.24
15	3.8730	26.40	51.51	33	5.7446	39.16	76.41
16	4.0000	27.27	53.20	34	5.8310	39.75	77.56
17	4.1231	28.11	54.84	35	5.9161	40.34	78.69
18	4.2426	28.92	56.43	36	6.0000	40.90	79.80
19	4.3589	29.72	57.97	37	6.0828	41.47	80.90
20	4.4721	30.49	59.48	38	6.1644	41.96	81.99
21	4.5826	31.24	60.95	39	6.2450	42.58	83.06
22	4.6904	31.98	62.39	40	6.3246	43.12	84.12

One of the important things to learn about a country is its boundaries. How far can one go in that country before reaching its border? So, in knitting one of the important questions is what are the limits? How far can one go, for instance, with the stitches per foot of yarn in either direction? This table answers that question for latch-needle rib machines, as it stands, and for flat-work machines if the stitches are for six inches of yarn. It is of course understood that these limits, and especially the loose-stitch limits, depend upon many conditions, such as opinion of what constitutes good fabric, strength of yarn, speed of machine, etc. But in any case this table constitutes a suggestion from which the reader may make his own table to suit his particular requirements.

The table is derived as follows:

Least number of stitches $= 6.83 \sqrt{No.}$

Greatest number of stitches $= 13.3 \sqrt{No.}$

YARN COUNTS

An equal *weight* of each of several yarns may be taken and each one may be numbered according to the *length* of that weight, as in the cotton count; or an equal *length* may be taken and each yarn may be numbered according to the *weight* of that length, as in the grain counts.

The first, or cotton count, method is called "the length-of-a-constant-weight system" and the other, or grain, method is called "the weight-of-a-constant-length system." For brevity the first is called "the constant-weight system" and the second "the constant-length system." Both are very simple but their application is made confusing by the use of many uncommon units of measure, such as hanks, jack draws, etc., the explanation of which is of historical interest principally.

Simple Units are Satisfactory. — All that it is necessary to know for practical purposes are the common equivalents of these units.

Cotton Count. — Suppose the pound is taken for the unit in the constant-weight system and one pound of a certain size yarn is found to be 840 yards long. Then one pound of a yarn half as heavy would be twice 840 or 1680 yards long. These numbers 840 and 1680 might be taken as the yarn counts, but they are too big for convenient use. So a larger unit of length than the yard, namely, 840 yards, is taken as the cotton-count unit of length. Consequently the cotton count of any yarn is the number of yards in a pound divided by 840, called a hank; so the first yarn was No. 1 and the yarn half as heavy was No. 2. Evidently in this system the number increases as the yarn becomes finer.

Grain Count. — Now suppose that 50 yards is taken as the unit of length in the constant-length system and grains as the unit of weight. Then a yarn of which 50 yards weigh one grain is one-grain yarn. A yarn twice as heavy weighs two grains and is called two-grain yarn. Therefore, in this system — the constant-length system — the number increases as the weight of the yarn increases.

Transforming between Systems. — Take a round piece of elastic. It has a number in each system. Stretch the elastic to twice its length. Its number has doubled in one system and halved in the other system. That is, for change in the yarn the number multiplies as much in one system as it divides in the other. Suppose the elastic is No. 1 cotton; that is, 52 grain, Cohoes. One multiplied by fifty-two equals fifty-two. After it is stretched twice its length it is No. 2 cotton and 26 grain, Cohoes. Two multiplied by twenty-six equals fifty-two, the same as before. And no matter how much the elastic is stretched, the product of its number in the two counts is fifty-two. Take the number of any yarn in any count of the constant-weight system and its number in any count of the constant-length system; multiply these two numbers together and the product will be a constant, which divided by the number of any yarn in one count will give its number in the other count. For instance, 13 cotton is 4 grain, Cohoes, $13 \times 4 = 52$. Then No. 10 cotton is 5.2 grain, Cohoes because $52 \div 10 = 5.2$, etc.

Transforming within Systems. — Transformation between counts in either system is effected by simple proportion. For instance, the cotton count and the worsted count are both of the constant-weight system and cotton number $\times \frac{3}{2}$ = worsted number. Similarly, the Amsterdam count and the Cohoes count are both in the constant-length system, and Amsterdam number $\times \frac{1}{2}$ = Cohoes number. On these two simple principles, division of a constant or multiplication of a ratio, depend all the yarn transformations.

The table on page 194 gives the constants for practical use in transformation between systems and convenient proportions for transformation within either system.

Yarn Count Definitions

The yards in a pound divided by	840	is the	cotton count
	560		worsted count
	1600		run
	300		cut or lea
	496		metric, strict
	992		metric, modified
The weight in grains of the following number of yards	$6\frac{1}{4}$	is the	Cohoes standard
	$12\frac{1}{2}$		Amsterdam standard
	20		American standard
	50		New Hampshire standard
	633.9*		neat-silk denier standard
	36.57		neat-silk dram standard

* Some authorities differ from this number of yards.

Technically, the weight in grains of $\left\{\begin{matrix}3\\6\end{matrix}\right\}$ jack draws is the $\left\{\begin{matrix}\text{Cohoes standard}\\\text{Amsterdam standard}\end{matrix}\right\}$ but $\left\{\begin{matrix}6\frac{1}{4}\\12\frac{1}{2}\end{matrix}\right\}$ are used as the equivalent lengths in yards.

COUNTS USED FOR DIFFERENT KINDS OF YARNS

Confusion in Yarn Numbering. — On page 190 is a list of the most used counts and the kinds of yarn for which they are used, but no such list is entirely dependable. For instance, 20 ramie may be metric, or metric modified, and if it is not known which, confusion is likely to result unless the individual can determine for himself. This is true of many other yarns. Consequently, any one who has to use different yarns should early form the habit of determining the number for himself instead of depending on guesses. See *yarn diameter*, from which the cotton count can be determined. Then by simple transformations into the counts supposed to be used, the actual one will be ascertained by its substantial agreement with one of the transformed numbers.

Difference in Ply-yarn Numbering. — Another source of confusion is the lack of agreement in ply-yarn numbers. Thirty two-ply cotton is really 15 cotton made of two thirty yarns twisted together. Thirty two-ply spun silk is really 30 yarn composed of two threads of 60 twisted together. Therefore, for cotton, divide the nominal number by the ply to get the real number; but for silk, neglect the ply except for general information. If the distinction cannot be remembered, but some of the yarn is available, dependence should be put on actual measurement.

Confusion between Multiple-ply and Multiple-thread Yarn. — Still another source of confusion is the lack of a distinguishing indication whether yarn is two-ply or two-thread.

Ply yarn is single yarn composed of finer yarns twisted together. Two-thread is an expression meaning that two single yarns are used as one. A two-thread fabric is generally made by running two separate threads into each feed used in making the fabric. The numerical ways of writing two-ply or two-thread 30 are 2/30, 2–30; 30/2, 30–2. In some localities one form means two-thread and the other two-ply, whereas in other localities the meaning is just the reverse. Consequently, when such an expression gets out of its locality, it is misunderstood. Moreover, it is so easy to forget which expression means two-ply, that there seems but little chance of agreement on a definite meaning for either form, even if a concerted effort should be made. Therefore, the only safe way apparent is to spell out two-ply or two-thread.

American Count. — Used in the northeastern part of the United States and Eastern Canada for numbering yarn made in the knitting mill.

Amsterdam Count. — This is merely a modification of the Cohoes count, used to obtain a more accurate weight. It is used principally through New York State for yarn made in the knitting mill.

Cohoes Count. — Used through the eastern part of New York State for yarn made in the mill.

Cotton Count. — Used almost universally for commercial cotton yarn, including mercerized cotton, also used for spun silk.

Cut or Lea. — Used in Great Britain for linen, ramie and fine jute, for which use it is called lea. Used for woolen yarn in Eastern Pennsylvania, where it is called cut.

Metric Standard. — Sometimes used for some yarns where the metric standard is obligatory. Ramie is numbered in this standard.

Metric Modified. — Used for linen and some cotton on the European Continent.

New Hampshire. — Used to some extent through the New England States.

Run. — Used for woolen yarns, other than worsted, in Great Britain and the United States.

Silk Denier. — Used extensively for raw silk, also used for thrown silk on the European Continent.

Silk Dram. — Used for thrown silk.

Worsted Count. — Used extensively in English-speaking countries for worsted.

EXPLANATION OF CONVENIENT EQUATIONS FOR DETERMINING THE NUMBER OF YARN IN THE CONSTANT-WEIGHT COUNTS

It is generally undesirable to reel an entire hank of yarn when it is necessary to determine the count, so it is convenient to have shorter lengths which will serve the purpose without necessitating reduction from the hank. The tabulation of convenient equations shows in the first row the definition equations, except that those of the metric system are converted into yards and pounds.

The second row is the same, with each term of the fraction divided by ten. It is evident from the first equation of the second row that if 84 yards of yarn be reeled and weighed, the number will be one-tenth divided by that weight. This length is long enough to give a reliable weighing, yet not long enough to be wasteful of either yarn or time. After a little use, the decimal

Convenient Equations for Determining the Number of Yarn in the Constant-weight Counts

General Equation. $\text{No.} = \dfrac{1}{\text{Weight of a constant length}}$

Cotton	Worsted	Run	
$\text{No.} = \dfrac{1}{\text{Wt. 840 yds.}}$ $\text{No.} = \dfrac{.1}{\text{Wt. 84 yds.}}$	$\dfrac{1}{\text{Wt. 560 yds.}}$ $\dfrac{.1}{\text{Wt. 56 yds.}}$	$\dfrac{1}{\text{Wt. 1600 yds.}}$ $\dfrac{.1}{\text{Wt. 160 yds.}}$	Weight in pounds
$\text{No.} = \dfrac{7000}{\text{Wt. 840 yds.}}$ $\text{No.} = \dfrac{1000}{\text{Wt. 120 yds.}}$	$\dfrac{7000}{\text{Wt. 560 yds.}}$ $\dfrac{1000}{\text{80 yds.}}$	$\dfrac{7000}{\text{Wt. 1600 yds.}}$ $\dfrac{1000}{\text{Wt. 228.6}}$	Weight in grains
$\text{No.} = \dfrac{8\frac{1}{3} \times \text{yds. weighed}}{\text{Wt.}}$	$\dfrac{12.5 \times \text{Yds. weighed}}{\text{Wt.}}$	$\dfrac{4.375 \times \text{Yds. weighed}}{\text{Wt.}}$	

Cut	Metric, modified	Metric, strict	
$\text{No.} = \dfrac{1}{\text{Wt. 300 yds.}}$ $\text{No.} = \dfrac{.1}{\text{Wt. 30 yds.}}$	$\dfrac{1}{\text{Wt. 496 yds.}}$ $\dfrac{.1}{\text{Wt. 49.6 yds.}}$	$\dfrac{1}{\text{Wt. of 992 yds.}}$ $\dfrac{.1}{\text{Wt. of 99.2 yds.}}$	Weight in pounds
$\text{No.} = \dfrac{7000}{\text{Wt. 300 yds.}}$ $\text{No.} = \dfrac{1000}{\text{Wt. 42.86 yds.}}$	$\dfrac{7000}{\text{Wt. 496 yds.}}$ $\dfrac{1000}{\text{Wt. 70.86 yds.}}$	$\dfrac{7000}{\text{Wt. 992 yds.}}$ $\dfrac{1000}{\text{Wt. 141.7 yds.}}$	Weight in grains
$\text{No.} = \dfrac{23\frac{1}{3} \times \text{Yds. weighed}}{\text{Wt.}}$	$\dfrac{14.11 \times \text{Yds. weighed}}{\text{Wt.}}$	$\dfrac{7.056 \times \text{Yds. weighed}}{\text{Wt.}}$	

point may be forgotten, since it will come in the right place from habit. All of the other equations in the second row are similar to the one just explained.

It is frequently customary to weigh in grains instead of pounds, so the third row gives the definition equations for use when the grain weight per hank is used. But since the hank is too long for ordinary weighing, the fourth row gives the grain weight equations with both terms divided by seven, which makes the numerator 1000, and provides a convenient length for reeling, the weight of which, divided into 1000, gives the number.

The fifth row gives equations for use when it is not convenient or desirable to reel a fixed length. For the cotton count, weigh whatever length is convenient or available and divide that weight into the length in yards multiplied by $8\frac{1}{3}$. Proceed similarly for the other equations.

SINGLE EQUIVALENT OF TWO OR MORE YARNS

Let N_1 and N_2 be the numbers of two yarns (in the constant-weight system, i.e., cotton, worsted, run, cut, metric) whose single equivalent is desired, say N_s.

By definition $$N_1 = \frac{1}{\text{weight of a constant length of } N_1},$$

$$N_2 = \frac{1}{\text{weight of a constant length of } N_2},$$

Therefore, $$\text{weight of a constant length of } N_1 = \frac{1}{N_1}.$$

$$\text{weight of a constant length of } N_2 = \frac{1}{N_2}.$$

Adding, total weight of a constant length of N_1 and N_2

$$= \frac{1}{N_1} + \frac{1}{N_2} = \frac{N_1 + N_2}{N_1 N_2}.$$

Inverting,

$$\frac{1}{\text{total weight of a constant length of } N_1 \text{ and } N_2} = \frac{N_1 N_2}{N_1 + N_2}$$
$$= N_s \text{ by definition.}$$

In other words, *the product of two yarn numbers divided by their sum is the number of the single equivalent.*

From which it follows that *the product of one yarn and the equivalent divided by their difference is the other yarn.*

Examples. — What is the single equivalent of No. 10 and No. 20?

$$\frac{10 \times 20}{30} = \frac{200}{30} = 6.67.$$

What yarn is required with an 18 to make 12?

$$\frac{18 \times 12}{18 - 12} = \frac{216}{6} = 36.$$

When three or more yarns are to be reduced, combine two at a time until the single yarn is obtained.

When the yarns are in the constant-length system, their numbers are simply added to obtain the number of the single equivalent. The ordinary counts in this system are Cohoes, Amsterdam, American, New Hampshire, neat silk denier, neat silk dram.

Explanation of Yarn-transformation Table

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The given count is at the left of the table. The required count is at the top.

Divide the whole number or multiply the fraction at the intersection of the two counts by the number to be transformed to get the number sought.

Examples. — What is No. 10 cotton in dram silk count? Find the name of the given count, cotton, on the left. Run along to the column headed silk, dram. The expression found there is 305. Since it is a whole number, divide it by the given number. $305 \div 10 = 30.5$, the dram silk number of No. 10 cotton.

What is 10-grain New Hampshire in the Cohoes count? Find the name of the given count, New Hampshire, on the left. Run along to the column headed Cohoes. The expression there is $\frac{25}{200}$. Since it is a fraction, multiply it by the given number 10. $\frac{25}{200} \times 10 = 1.25$, the Cohoes number of 10-grain New Hampshire.

Yarn Rules for Different Yarn Counts

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This table gives the yarn-for-cut rules transposed into the yarn counts used in America. Attention is called to the fact that the transposition is made according to the yarn numbers and not according to the diameters, although the last method is right.

Yarn-transformation Table. For explanation see page 193

	American	Amsterdam	Cohoes	Cotton	Cut	Metric, standard	Metric, modified	New Hampshire	Run	Silk denier	Silk dram	Worsted
American	....	50/80	25/80	167	467	282	141	200/80	88	2535/80	146/80	250
Amsterdam	80/50	....	25/50	104	292	176	88	200/50	55	2535/50	146/50	156
Cohoes	80/25	50/25	....	52	146	88	44	200/25	27	2535/25	146/25	78
Cotton	167	104	52	....	112/40	68/40	34/40	417	21/40	5280	305	60/40
Cut	467	292	146	40/112	....	68/112	34/112	1167	21/112	14,790	853	60/112
Metric, standard	282	176	88	40/68	112/68	....	34/68	706	21/68	8,950	516	60/68
Metric, modified	141	88	44	40/34	112/34	68/34	....	353	21/34	4,470	258	60/34
New Hampshire	80/200	50/200	25/200	417	1,167	706	353	....	219	2535/200	146/200	625
Run	88	55	27	40/21	112/21	68/21	34/21	219	....	2,770	160	60/21
Silk denier	80/2535	50/2535	25/2535	5280	14,790	8950	4470	200/2535	2770	....	146/2535	7920
Silk dram	80/146	50/146	25/146	305	853	516	258	200/146	160	2535/146	....	457
Worsted	250	156	78	40/60	112/60	68/60	34/60	625	21/60	7,920	457	

Yarn count	Circular spring-needle loop-wheel knitting machine for flat work			Circular latch-needle knitting machine for rib work		
	Gauge (needles per 1½ inches)			Cut (needles per 1 inch, cylinder)		
	Light	Average	Heavy	Light	Average	Heavy
American	$\frac{5,000}{G^2}$	$\frac{6,667}{G^2}$	$\frac{10,000}{G^2}$	$\frac{667}{C^2}$	$\frac{1,000}{C^2}$	$\frac{1,333}{C^2}$
Amsterdam	$\frac{3,125}{G^2}$	$\frac{4,166}{G^2}$	$\frac{6,250}{G^2}$	$\frac{417}{C^2}$	$\frac{625}{C^2}$	$\frac{833}{C^2}$
Cohoes	$\frac{1,562}{G^2}$	$\frac{2,083}{G^2}$	$\frac{3,125}{G^2}$	$\frac{208}{C^2}$	$\frac{313}{C^2}$	$\frac{416}{C^2}$
Cotton	$\frac{G^2}{30}$	$\frac{G^2}{40}$	$\frac{G^2}{60}$	$\frac{C^2}{4}$	$\frac{C^2}{6}$	$\frac{C^2}{8}$
Cut	$\frac{G^2}{11}$	$\frac{G^2}{14}$	$\frac{G^2}{21}$	$\frac{C^2}{1.4}$	$\frac{C^2}{2.1}$	$\frac{C^2}{2.9}$
Metric, strict	$\frac{G^2}{18}$	$\frac{G^2}{24}$	$\frac{G^2}{35}$	$\frac{C^2}{2.4}$	$\frac{C^2}{3.5}$	$\frac{C^2}{4.7}$
Metric, modified	$\frac{G^2}{35}$	$\frac{G^2}{47}$	$\frac{G^2}{71}$	$\frac{C^2}{4.7}$	$\frac{C^2}{7.1}$	$\frac{C^2}{9.4}$
New Hampshire	$\frac{12,500}{G^2}$	$\frac{16,667}{G^2}$	$\frac{25,000}{G^2}$	$\frac{1,667}{C^2}$	$\frac{2,500}{C^2}$	$\frac{3,333}{C^2}$
Run	$\frac{G^2}{57}$	$\frac{G^2}{76}$	$\frac{G^2}{114}$	$\frac{C^2}{7.6}$	$\frac{C^2}{11.4}$	$\frac{C^2}{15.2}$
Silk, denier	$\frac{158,460}{G^2}$	$\frac{211,280}{G^2}$	$\frac{316,920}{G^2}$	$\frac{21,130}{C^2}$	$\frac{31,690}{C^2}$	$\frac{42,260}{C^2}$
Silk, dram	$\frac{9,143}{G^2}$	$\frac{12,190}{G^2}$	$\frac{18,285}{G^2}$	$\frac{1,219}{C^2}$	$\frac{1,829}{C^2}$	$\frac{2,438}{C^2}$
Worsted	$\frac{G^2}{20}$	$\frac{G^2}{27}$	$\frac{G^2}{40}$	$\frac{C^2}{2.7}$	$\frac{C^2}{4}$	$\frac{C^2}{5.3}$

Numbers	Squares	Numbers	Squares
4.0	16	20	400
4.5	20	21	441
5.0	25	22	484
5.5	30	23	529
6.0	36	24	576
6.5	42	25	625
7.0	49	26	676
7.5	56	27	729
8.0	64	28	784
8.5	72	29	841
9.0	81	30	900
9.5	90	31	961
10.0	100	32	1024
11.0	121	33	1089
12.0	144	34	1156
13.0	169	35	1225
14.0	196	36	1296
15.0	225	37	1369
16.0	256	38	1444
17.0	289	39	1521
18.0	324	40	1600
19.0	361		

Yarn Diameter and Coils, from Dia. = $\frac{1}{21\sqrt{No.}}$

No.	Dia.	Coils per 1 in.	Coils per ½ in.
2	.033670	29.700	14.850
3	.027493	36.370	18.185
4	.023810	41.995	21.000
5	.021295	46.955	23.480
6	.019441	51.490	25.720
7	.017998	55.557	27.780
8	.016835	59.400	29.700
9	.015873	63.000	31.500
10	.015057	66.415	33.207
11	.014357	69.650	34.825
12	.013746	72.750	36.375
13	.013207	75.715	37.855
14	.012725	78.580	39.290
15	.012294	81.340	40.667
16	.011904	84.000	42.000
17	.011567	86.450	43.225
18	.011223	89.100	44.550
19	.010925	91.530	45.765
20	.010646	93.930	46.965
21	.010391	96.230	48.115
22	.010152	98.510	49.250
23	.009929	100.720	50.357
24	.009720	102.880	51.440
25	.009523	105.010	52.503
26	.009366	106.760	53.380
27	.009164	109.130	54.560
28	.008999	111.110	55.560
29	.008843	113.080	56.540
30	.008694	115.030	57.510
31	.008553	116.920	58.460
32	.008418	118.790	59.395
33	.008290	120.630	60.310
34	.008167	122.450	61.223
35	.008049	124.240	62.120
36	.007937	125.980	62.995
37	.007829	127.730	63.865
38	.007725	129.500	64.750
39	.007625	131.150	65.570
40	.007529	132.820	66.410

But there is yet so little information about yarn diameters that no transposition could be made if the yarn numbers were not used. These formulas will be found quite reliable — much more so than guesses — but their principal value is in the simplicity of their form rather than in the constants given, since knitting is in such an unadvanced condition that there is not sufficient data on which to base absolutely reliable constants. But such are not necessary, since, as a rule, each knitter needs constants of his own to meet his own conditions of yarn and stitch, depending on the trade to which he caters. These simple equations give him the models from which to make his own rules. Multiplication and division are the only knowledge needed for their use, except perhaps, that the square of a number is that number multiplied by itself. But a table of squares is given, so that the squares may be read off without the inconvenience of computation. Let the knitter take the rule that applies to his machine and yarn count and try it. Suppose he uses latch-needle rib machinery and numbers his yarn in runs. If he wants to make average weight goods, his rule from the table is Runs = $\frac{\text{Cut}^2}{11.4}$. Suppose he is using 6 cut. The square of six is 36, obtained either mentally or from the table of squares. Then the yarn for 6 cut is 36 ÷ 11.4 or 3.2, say 3 run yarn, for short. If this is too heavy, try cut squared, divided by 10. If that fits the case, it is easily remembered and can be worked mentally. This rule will hold for similar conditions on all other cuts. Perhaps the knitter uses a machine altogether different from any mentioned in the rules. That makes no difference. The rule is universal. Only the constant needs to be changed. Square the needles per inch or the gauge, divide by the yarn used on that gauge and the quotient is the constant for all other gauges of that kind of machine. If the yarn count is in the constant length system, such as grains, the constant has to be divided by the square of the cut or gauge as the case may be, as is shown by the table.

Two precautions are advisable.

The first is to make sure that the yarn used to determine the constant is the right size for that purpose. If it is very heavy for the cut, then the equation will call for very heavy yarn in every case.

The other precaution is to avoid the use on a coarse cut of a constant determined on fine or even average cuts. The reason for this is that knitting machinery is seldom symmetrically designed on the extreme cuts and especially on the extremely coarse cuts. Consequently, if a certain diameter of yarn is perfectly satisfactory for a fine cut, a proportionately heavier one might overload a very heavy cut. Of course, if the constant has been determined on a cut comparatively near the one to be used, even if they are both coarse, the rule is reliable.

The Junction of any Two Yarn Numbers Gives Approximate Single Equivalent

Yarn No.	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6
6	5.4	5.3	5.3	5.3	5.3	5.2	5.2	5.1	5.1	5.0	5.0	4.9	4.9	4.8	4.7	4.6	4.5	4.4	4.2	4.0	3.8	3.4	3.0
8	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.5	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.7	5.5	5.3	3.0	4.8	4.4	4.0	
10	8.3	8.3	8.2	8.2	8.0	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.2	8.1	6.9	6.7	6.4	6.2	5.8	5.5	5.0		
12	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.7	8.6	8.4	8.2	8.0	7.8	7.5	7.2	6.9	6.5	6.0			
14	10.9	10.8	10.7	10.6	10.5	10.4	10.2	10.0	9.9	9.7	9.5	9.3	9.1	8.9	8.6	8.2	7.9	7.5	7.0				
16	12.1	12.0	11.9	11.6	11.6	11.4	11.3	11.0	10.9	10.7	10.4	10.2	9.9	9.6	9.3	8.9	8.5	8.0					
18	13.2	13.1	12.9	12.8	12.6	12.4	12.2	12.0	11.8	11.5	11.3	11.0	10.6	10.3	9.9	9.5	9.0						
20	14.3	14.1	13.9	13.8	13.6	13.3	13.1	12.9	12.6	12.3	12.0	11.7	11.3	10.9	10.5	10.0							
22	15.3	15.1	14.9	14.7	14.4	14.2	13.9	13.7	13.4	13.0	12.7	12.3	11.9	11.5	11.0								
24	16.2	16.0	15.8	15.5	15.3	15.0	14.7	14.4	14.0	13.7	13.3	12.9	12.5	12.0									
26	17.1	16.9	16.6	16.4	16.1	15.8	15.4	15.1	14.7	14.4	13.9	13.5	13.0										
28	18.0	17.7	17.4	17.1	16.9	16.5	16.1	15.8	15.4	14.9	14.5	14.0											
30	18.8	18.5	18.2	17.9	17.5	17.1	16.8	16.4	15.8	15.5	15.0												
32	19.5	19.2	18.9	18.5	18.2	17.8	17.4	16.8	16.5	16.0													
34	20.2	19.9	19.6	19.2	18.8	18.4	17.9	17.5	17.0														
36	20.9	20.6	20.2	19.8	19.4	19.0	18.5	18.0															
38	21.6	21.2	20.8	20.4	20.0	19.5	19.0																
40	22.2	21.8	21.4	21.0	20.5	20.0																	
42	22.8	22.4	22.0	21.5	21.0																		
44	23.4	23.0	22.5	22.0																			
46	24.0	23.5	23.0																				
48	24.5	24.0																					
50	25.0																						

FIGURE DESIGNING WITH PATTERN WHEELS

Knit fabric is most extensively produced in the form of a tube by circular motion, and circular motion is generally described in the terms of the motion of the hands of a clock.

Knitting-machine Motion. — The motion of the machine in Illustration 1 is contrary to that of the hands of a clock and so the machine is called counter-clockwise or anti-clockwise. If the motion were in the opposite direction, it would be called clockwise, since it would then be just like that of a clock, which is shown by the one illustrated under the machine for the purpose of comparison. It is evident that the clock is on its back and that the clock case is taken as the stationary portion just as the frame of the machine is taken as the stationary portion with respect to the needles. In this case, the frame of the machine is called the stator, which means stationary portion and the cylinder and dial are called the rotor, which means rotating portion. Evidently the machine is viewed from above, just as is the clock. However, if this machine were turned upside down and operated with its legs towards the ceiling, it would make exactly the same cloth. This shows that although it is permissible to classify knitting machinery according to its motion as viewed from above, still that classification will not properly describe its motion with respect to the fabric which it produces; for the direction of motion is reversed by inversion of the machine, but the fabric is not changed. Again, if instead of the needles moving anti-clockwise and the cams keeping stationary, the needles were kept stationary and the cams were moved clockwise, still the cloth would be the same, although the motion of the machine would be different by the above mentioned classification. In order to overcome all these difficulties and still adopt conventions which may be readily learned and which possibly will not need to be changed, it seems best to make the following agreements:

Top of Fabric. — (1) That the top of the fabric is to be that portion which is nearest the needles, or, in other words, the portion which left the needles last. This is generally accepted of plain fabric, although it is contrary to American practice in regard to fabric with figure designs. But it is almost impossible to get a universal standard without contravention of some local standards and there are a number of good reasons other than that already mentioned for considering the top of the design to be the

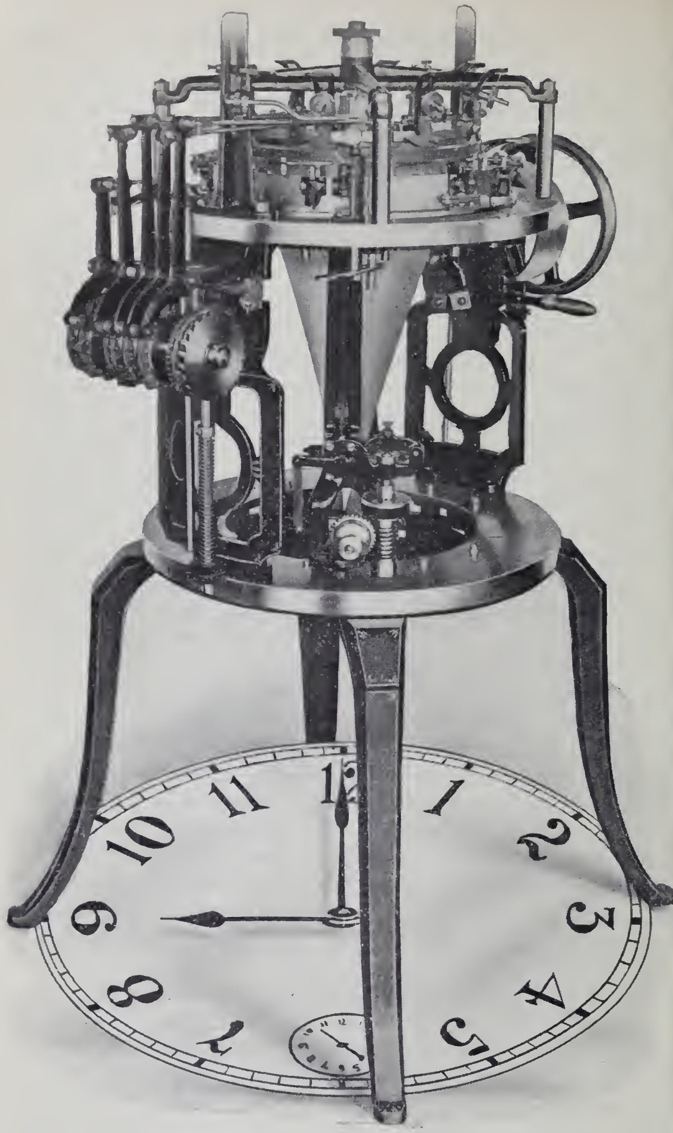


Illustration 1.

This machine is anti-clockwise since its motion is opposite to that of the hands of a clock.

Clockwise motion is the same as that of the hands of a clock.

portion which left the needles last. For instance, fabric of this kind can generally be raveled only from the end which left the needles last, consequently, it is natural to keep this end up to examine a given sample. Also the figure of the design may well be regarded as being built up from below like most structures in which the first courses are at the bottom.

Face of Fabric. — (2) The face of the fabric is that side towards which the new loop is drawn through the old loop. This convention is generally accepted, so it is repeated here as a reminder instead of an introduction.

Fabric Considered to Move. — (3) The fabric is to be considered the moving portion of the machine, that is, the rotor. With this agreement, it matters not whether the guide or the fabric really moves. If the fabric revolves, there can be no confusion. If the guide moves, the fabric is considered to move in the opposite direction, since it is only their relative motion which counts in the fabric. This will be made clear by reference to Illustration 1, in which the machine is considered anti-clockwise, because the fabric moves in that direction. If, now, the fabric were kept stationary and the cam ring were moved in the opposite direction, the structure of the fabric would not be changed, therefore, this machine would still be classed as anti-clockwise. The agreement on this convention reduces the complexity of the question one-half, since it cuts in two the number of machines to be considered.

Designation of Motion. — (4) Since, when the tube of fabric is cut open, the direction of circular motion can no longer be determined, the words " right " and " left " are to be used with reference to the fabric — viewed face out, top up — instead of " clockwise " and " anti-clockwise " to indicate the motion of knitting.

The fabric from the machine in Illustration 1 is top up and face out. Therefore, the knitting motion considered with respect to the face of the cloth is right-hand. Now, consider the French circular machine shown diagrammatically in Illustration 2. The fabric revolves clockwise, runs downward, and faces inward. It is evidently right side up, but wrong side out. Consequently, from the inside, the motion of knitting is right-hand with respect to the fabric. Notice that one change of position was necessary to view the fabric correctly and that one change of the apparent direction of motion was necessary to obtain the correct direction. Again, consider the American loop-wheel machine in Illustration 3, in which the fabric revolves anti-clockwise, runs upward and faces inward. Evidently, it is wrong side up and wrong side out, consequently two changes of position are necessary to give the correct view position with respect to the face of the fabric. But the first change of position reverses the apparent motion, and the second brings it back again where it was at first. From this comes the general rule:

Rule for Motion. — *To get the correct motion of knitting reverse the apparent motion of the fabric as many times as it is necessary to change position in order to view the face right side up.* The knitter should be prepared to meet sixteen types of machine. The agreement that the fabric shall be considered the moving portion reduces the number to eight. Table 1 illustrates the eight representative types, describes the sixteen types, and shows the direction of knitting motion for each one.

The diagrams are drawn with the portion of the fabric on the needles larger in diameter than the first knit portion, and the latter is shown with what appears like the cutting tooth of a bit or auger. The reason for showing the tooth is that the circular machine really knits a ribbon of fabric and loops the edges of the ribbon together. This may be understood from Illustration 4 which represents an anti-clockwise multiple-feed machine in which the fabric runs downward and in which one feed is supplied with black yarn, while the others are supplied with white yarn. This machine knits a ribbon of fabric as many courses wide as it has feeds, which width is from black course to the next black course, and at each revolution loops the adjoining edges of that ribbon. Therefore, if the tube is cut around through one black course and then cut lengthwise along one wale to the next black course, the end of the tube will show the tooth

Illustration 2.
French machine.

Illustration 3.
American machine.

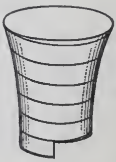


Illustration 4.
Ribbon structure of circular fabric.

illustrated. The same appearance may be obtained by raveling all the threads to a certain wale. The path of this ribbon is called a helix, and the first formed portion always points in the combined direction of motion in which the fabric is formed. In this case that direction is to the right and downward. If this ribbon construction of the fabric and the direction of inclination are remembered, figure designing with pattern wheels is readily understood.

Pattern Wheels for Latch-needle Machine. — Evidently, these pattern wheels do not act on a particular needle, nor do they act directly, but act through a cam on an entire set of needles or on a fixed division of a set, as when the set of needles is operated by two independent sets of cams for making vertical stripes. On the contrary, the pattern wheel for figure designs acts directly on each individual needle of its set or division of a set, and is, theoretically, capable of making any needle operate in a contrary way from any other needle. For instance, at one revolution it might make a given needle tuck and the next needle knit, whereas at the next revolution it might make each one do just the reverse; that is, it is capable of selecting needles, and when used in latch-needle work is actually called the selector. See "Tuck-stitch figures." In spring-needle machines it is called the presser because it presses the beards of the needles where it clears the stitches and mispresses (fails to press) where it tucks.

Spring-needle Pattern Wheel. — The ordinary spring-needle presser is a bronze wheel about 3 inches in diameter with a hub in the middle for its supporting stud and with two kinds of nicks around its circumference, shallow ones called prints to keep the presser traveling with the needles, and deep nicks to make the pattern effects.

Material for Pattern Wheels. — The material of the presser should be durable, should cut readily, and should not roughen the needles. Bronze meets the requirements quite satisfactorily, but iron, soft brass and even fiberoid are used. The latter may be cut or filed very readily; it is quite durable and is economical, since as generally constructed the hub or bushing is removable, so that the only cost for renewal of a presser is that for a new fiberoid disc. Also with this construction several discs may be clamped together and cut at one time when duplicates are required.

TABLE I

Machines and Fabric Classified According to Knitting Motion

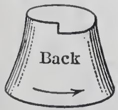
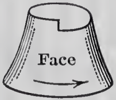
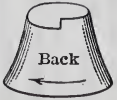
	Direction of motion of cylinder	Direction of motion of yarn carrier	Direction in which fabric is drawn	Direction in which fabric faces	Classification of fabric
1 	Anti-clockwise Stationary	Stationary Clockwise	Down	Outside	Right-hand
2 	Clockwise Stationary	Stationary Anti-clockwise	Down	Inside	Right-hand
3 	Anti-clockwise Stationary	Stationary Clockwise	Up	Inside	Right-hand
4 	Clockwise Stationary	Stationary Anti-clockwise	Up	Outside	Right-hand

TABLE I (*Continued*)

Machines and Fabric Classified According to Knitting Motion

	Direction of motion of cylinder	Direction of motion of yarn carrier	Direction in which fabric is drawn	Direction in which fabric faces	Classification of fabric
5 	Anti-clockwise Stationary	Stationary Clockwise	Down	Inside	Left-hand
6 	Clockwise Stationary	Stationary Clockwise	Down	Outside	Left-hand
7 	Anti-clockwise Stationary	Stationary Clockwise	Up	Outside	Left-hand
8 	Clockwise Stationary	Stationary Anti-clockwise	Up	Inside	Left-hand

Special Pattern Wheels. — The designs are generally originated in the mill and the patterns worked out there, after which the pressers are ordered from the knitting machine shop according to the specified pattern. In mills which make considerable quantities of pattern work the cutting is done in the mill's repair shop. This has the advantage of facilitating the work and of keeping the design secret until after the goods are upon the market, which insures the mill one season's exclusive run on the design. However, the knitting machine makers probably seldom, if ever, betray such confidence, so frequently knit-goods manufacturers who are not familiar with pattern work — fancy work, it is frequently called — send samples of patterns to the knitting machine shop with an order for pressers to duplicate the sample or to make similar designs adaptable to the machines in question. This puts all of the responsibility for the work on the knitting machine shop, which some shops offset by a charge for the analysis of the sample.

Advantages of Making Pattern Wheels in the Mill. — The original reasons for resorting to the machine shop were that it was equipped with cutting machinery, whereas the mill was not, and that the builder of the machine was familiar with the numbers of needles in different-sized machines and with the rules for determining the sizes of the pressers. But since modern mills are generally equipped with a gear cutter, and since presser calculations are very simple, the practice of keeping all of this work within the mill is increasing. There are many other excellent reasons why it should increase. For instance, the knitter can tell exactly how many feeds he is running on each machine, and just how many needles are in his cylinders, whereas the records of the machine shop may not be sufficiently complete to show all this. Besides, the mill management may have the pressers made according to the urgency of its own particular case, whereas the machine shop is supposed not to give priority to any particular order. Moreover, in case of a mistake it may be corrected in the mill with the least delay. And finally the knitter should make his own designs and his own presser diagrams, for it is generally easier for the knitter to learn this than it is to convey clearly to a machinist just what is wanted.

Relation of Diameter and Cuts. — If the machines have 20 needles to the inch and the pattern contains 180 needles, then the circumference of the presser should be $180 \div 20$ or 9 inches, and the diameter will necessarily be $9 \div 3.14$ inches = 2.86, provided no allowance is made for tipping the presser or for the difference between pitch diameter and actual diameter. In many cases no allowance is made. But the reasons for such allowances should be understood for use when they are needed.

Tip of Spring-needle Pressers. — In most American loop-wheel machinery the presser is kept in position on its stud by its own weight, but this cannot always be depended upon, for the action of the needles has a tendency to raise the presser; consequently, it is tipped so that the edge which is approaching the needles is a little lower than the edge which is leaving them. Five degrees is a conventional allowance. The necessary allowance is sufficient to keep the presser down surely against the shoulder on the stud. If it is not kept down, knitting will stop at that feed, since no stitches will be cleared there. Also, the yarn fed at that feed will run loose and the design will be spoiled. If the presser is tipped, the marks on the presser should be farther apart than the needles, since the edge of the presser has to travel farther than the needles.

Pitch Diameter. — The allowance for difference between pitch diameter and actual diameter would be absolutely necessary if the presser teeth were long like gear teeth, but for loop-wheel machines they are not. The cut which engages the needle is generally only two or three hundredths of an inch deep, which depth is negligible.

Diameter Allowance. — In the light of the above, a fairly safe rule is to begin with the presser two per cent larger than the calculations require, and to depend on the tip of the presser for the exact adjustment of the cuts to the needles. Special cases require special allowance, but the knitter can undoubtedly make these better from experiment than from general rules.

Latch-needle Pattern Wheels. — Selectors for latch-needle machines are not included in the above, for they run at a fixed angle, are generally secured to the stud, and operate more like gears. Moreover, they are generally made in the knitting-machine shop, since they are preferably made of hardened steel, and since their manufacture requires more mechanical skill than the knitter may reasonably be expected to have.

Plain Pressers Like Raising Cams. — The fundamental feature of the pattern wheel is well shown by comparison with the plain presser used in loop-wheel machines. (In latch-needle machines the cam which clears the latch corresponds to the plain presser.) The plain presser presses all of the needles, so it may be any size, provided its arc of contact is sufficient to enable surely landing the stitch. If it is small, it merely revolves faster than if it is large, but even then it does not have to keep step with the needles. This is shown by the fact that in many cases plain pressers are merely cams, called flat or stationary pressers. These pressers correspond exactly with the raising cams in the latch-needle machine, in that they are no respecters of needles.

Pattern Wheel must Count Needles. — On the contrary, the pattern presser must be a respecter of needles, which necessitates that it must keep track of every needle — actually count needles. This is the fundamental requirement of the pattern presser. It follows then that it need not be a wheel, or any particular device, so long as it keeps its count. Consequently, a chain meets the requirements, or a magazine of pressers arranged to displace each other successively in certain order.

Relation of Size of Presser to Number of Patterns. — The pattern presser really counts patterns, that is, groups of needles, instead of individual needles, which individual counting is done by the cuts of the pattern. Therefore, the size requirement of the presser is that it shall contain a whole number of patterns. It must be large enough to contain one pattern, and after that, it may contain as many more as convenience dictates, since the design is unaffected by the number of patterns contained by the presser.

Limitations to Size of Presser. — There are practical limitations to the size of the presser too numerous for generalization, but a few of them are of sufficient importance to warrant their mention. On the small side, the limit is generally the least number of cuts which will insure landing the stitch; although sometimes the hub of the presser is so big that the number of cuts has to be correspondingly big. However, this difficulty is purely mechanical; consequently, it may be overcome by the use of a small stud and hub. On the large side, there are such limitations as the available space on the machine, the weight of presser which the needle beards can safely drive, the cost of turning and cutting a big wheel, and the extent of the index with which the cutting is to be done. It is not infrequent for a knitter to make a design for a certain number of feeds and then find that the available space is insufficient for the same number of pressers large enough to carry the pattern.

Position of Presser. — The position of the presser with respect to the needle line affects the design. For instance, changing a presser from the outside of the needle line to the inside inverts the design. Therefore, the position of the presser is required for intelligent designing. Illustration 5 shows the positions which are likely to be encountered. The machine is anti-clockwise with

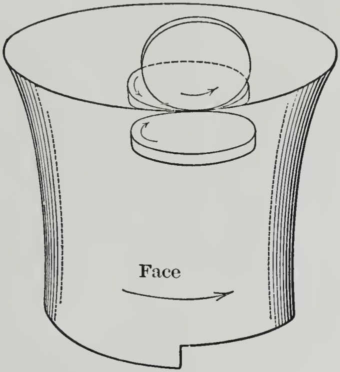


Illustration 5.
The three usual presser positions.

the fabric running downward and facing outward. However, theoretically, the kind of machine has nothing to do with the position of the pressers, since the latter might be placed in any one of three positions on any machine.

Representing Presser by a Paper Ring. — It is evident that the directions of motion of the inside presser and the outside presser are opposite. It is also evident that the vertical presser may be considered to revolve like the inside presser or the outside presser according to whether its outside face or inside face is taken as the top. It is shown farther on that a paper pattern may be formed in a circle to represent the circumference of the presser. Then exact comparison may be made between the actual presser and the circular pattern, with the circular pattern held in the position of the presser and with the operating side of the pattern considered the same as that of the presser.

Printing Presser with Needles. — When it is inconvenient to have pressers cut by machine, the following method is sometimes used. The presser blank is turned to the calculated size, or slightly over that size, and then run on the knitting machine with moderate pressure against the shanks of the needles, where they are stiff. The presser becomes marked by the needles according to the needle spacing. These marks are counted and there should be as many as there are needles in the pattern, or in a multiple of it. If there are too many prints in the presser, it is turned down slightly and reprinted until it contains just the right number. Then the prints which are to skip needles are made deep enough and wide enough to skip with the use of a file or a hack saw or both.

Since designs with tuck stitches are the commonest, the discussion is continued with respect to tuck work; but the principles apply to practically all circular pattern devices.

Presser Like a Wheel Printing a Ribbon. — From the fact that the presser operates directly on the needles it may be considered to operate directly on the fabric; and since the fabric travels in a helical path, the presser may be considered to be a printing wheel beneath which the ribbon of fabric runs and receives the pattern impression. The subject will be treated in accordance with these considerations, starting with a single pattern wheel. Suppose that the circumference of the pattern wheel divides a whole number of times — that is, divides integrally — into the circumference of the fabric. Then whatever impressions are on the presser will fall in line with the wales and so make what are called vertical stripes. Now, the pattern on the presser is not changeable without recutting the presser, so the pattern is considered to be fixed.

Causes of Changes in the Figures. — The different figures in the fabric which may be obtained from any pattern are caused by change in the number of needles, or by change in the direction of motion of the machine. Evidently, change in the direction of motion of the machine changes the end of the pattern which comes on the fabric first and change in the number of needles tips the stripes out of their vertical position. The essential part of figure designing consists of the few simple principles which connect these changes of needles and of motion with the resulting changes in the vertical stripes.

Definition of Pattern. — In order to avoid confusion it is necessary to understand clearly what each term means and to restrict its use to that particular meaning. One of the obstacles heretofore in the way of a clear description of the principles of figure designing has been the lack of such understanding. For instance, it has been customary to use the term pattern to designate both the impressions on the circumference of the presser and the figures in the fabric obtainable with it. But since there may be at least as many of these figures as the number of needles in one circumference of a non-repeating presser, it is evidently necessary to distinguish between the arrangement of impressions on the presser, which is fixed, and the result in the fabric, which

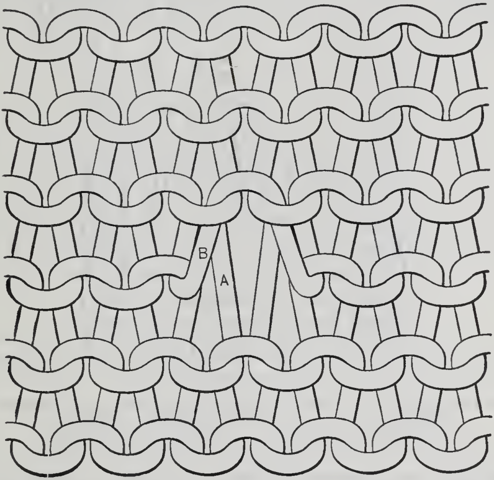


Illustration 6.

A single tuck stitch viewed from the back of the fabric. A is the *held loop*, B is the tuck loop.

is variable. Therefore, *it is advisable to restrict the term pattern to the impressions around the circumference of the presser and to its duplication along the ribbon of fabric.* Moreover, some pressers are sufficiently large to contain the pattern more than once, so *the actual pattern is any successive portion of the circumference of the presser or of the ribbon of fabric which does not repeat itself.*

Tuck Stitch. — Illustration 6 shows a tuck stitch viewed from the back of the fabric. It is seen to consist of a V-shaped loop with the point upward and a long loop from the next lower course, through both of which a loop from the next higher course is drawn. The term tuck stitch is also used to indicate either the inverted V-shaped loop or the long loop. In order to avoid confusion it seems advisable to restrict the term tuck stitch to the combination just described, to call the inverted V-shaped loop the tuck loop and to call the long loop the held loop. This agrees well with the conventions and the facts, since the inverted V-shaped loop is produced at what is called the *tuck* feed and since the long loop is *held* over a course before it is cleared.

Illustration 7 shows a double-tuck stitch viewed from the back of the fabric. In this there are two tuck loops and the held loop

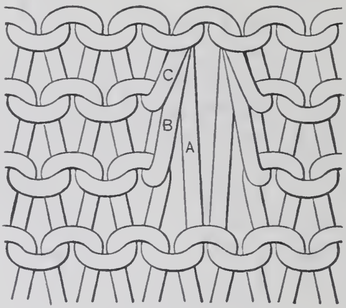


Illustration 7.

A double tuck stitch viewed from the back of the fabric. A is the *held loop*. B is the first tuck loop. C is the second tuck loop.

is carried over two courses before it is cleared. When the tuck stitch contains more than one tuck loop, these are numbered in the order of their formation, so in Illustration 7 the longest *tuck* loop is No. 1 and the shortest one is No. 2. The longest loop of all remains the held loop.

Illustration 8 shows four adjoining tucks in the same course viewed from the back of the fabric. Each held loop is like the one in the single tuck, but the tuck loop appears as a long loose thread on the back of the fabric.

Before the stitches are further discussed, it should be stated that these sketches are diagrammatic and that the actual stitches would not always be recognized from sketches of this kind. Indeed, one of the remarkable things about tuck-stitch combinations is how different they look from what is expected. This introduces one of the principal characteristics of tuck stitches, the distortion which they produce in the fabric.

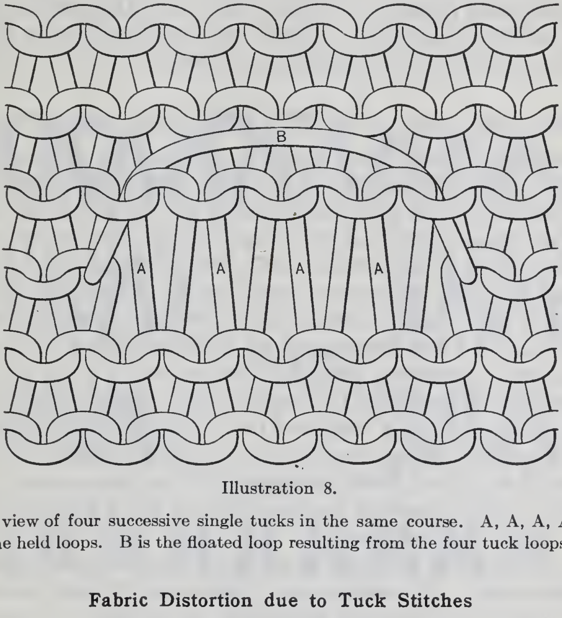


Illustration 8.

Back view of four successive single tucks in the same course. A, A, A, A are the held loops. B is the floated loop resulting from the four tuck loops.

Fabric Distortion due to Tuck Stitches

In plain fabric one of the requirements for good fabric is to have the stitches all alike. But consideration of Illustration 6, single tuck, shows that if the yarn is fed uniformly, the tuck loop will be too long and the held loop will be too short. Consequently tuck stitches pucker the fabric in the locality of the tucks. The general effect is to shorten the fabric along the wales and widen it along the courses. For this reason smaller-size cylinders are needed for tuck work than for plain work. The extent of the change depends largely on the proportion of tuck stitches to plain stitches. Some designs contain so few tucks that the widening is inappreciable.

It is evident that the held loop has a tendency to steal some yarn from its adjoining loops in the same course; and, although it is not so evident, still it is just as true, that the tuck loop has a tendency to lend some yarn to the adjoining loops in its course. Therefore, as a general rule, *loops next to held loops in the same course are short, and loops next to tuck loops in the same course are long.* But it must be remembered that a series of tucks close together may produce a different effect than that produced by one isolated tuck stitch. Indeed, the variations due to stitch distortion alone are too numerous to classify.

Tuck-stitch Limits

Necessary to clear Held Loops. — It was shown that the tuck stitch involves the drawing of a loop through the tuck loop and the held loop. In other words, unless the tuck loop and held loop are cleared, there can be no tuck stitch. This is true practically as well as theoretically, since the needle must be cleared or else it or the loops on it must break. Consequently, the strength of the yarn is a factor which determines how many tuck loops may be carried on one needle. The strength of the needle is generally sufficient, provided the burden of loops can be thoroughly cleared within reasonable time, but it is difficult to clear many loops at a time, and failure to clear them allows so many loops to accumulate on the needle that their combined strength ultimately bends or breaks it. From five to seven tucks on the needle, according to the yarn and the machine, is considered the practical limit.

The number of adjoining tucks along a course is limited in a different way. Consideration of Illustration 8 shows the tuck loop to be a long loose loop on the back of the fabric. In reality, the loop is longer than it is shown, for two reasons: one is that the fabric generally narrows on leaving the needles, which makes the loop longer by comparison; and the other is that there was as much yarn supplied to this loop as to the four stitches which it crosses. The result is that the back of the fabric is not only unsightly, but these loops catch and tear in use, which makes the fabric less durable than it would be otherwise. Six adjoining tucks along a course is considered the practical limit.

The Tuck Loop is kept out of the Face of the Fabric

Examination of any of Illustrations 6, 7 and 8 shows that the tuck loop is kept on the back of the fabric. This is not of much importance when the yarn is all of the same color, but when different colored threads are used, it affords an opportunity for keeping the tucked color out of the face at intervals. This introduces the customary arrangement of feeds. We have to start with: a tuck must be cleared; the number of adjoining tucks both horizontally and vertically is limited; and two different colors are generally used. If it were not for the first two conditions, the idea would at once suggest itself to use two colors

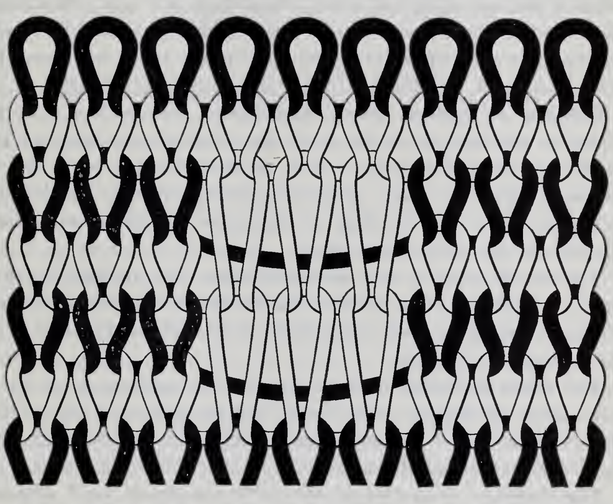


Illustration 9.

Face view of a white block in a mixed field. The floated threads are seen behind the white *held loops*.

of marked contrast, say black and white, and to reverse them alternately from face to back. This would make, say, a black figure on a white field, which constitutes a distinct design. But since the number of successive tucks in either direction is advisably not over six, the greatest extent of the figure or of any part of the field would be six stitches in height and in width, and even that size is accompanied with much puckering. The other alternative is to keep the first color in the face, to keep the second color in the face part of the time, — when it combines with the first color to make a mixed field, — and to throw the second color to the back during the rest of the time in order to leave the first color entirely in the face for a short interval to form the small solid figure. Illustration 9 shows the face of a piece of fabric made in this way. The black thread is thrown back out of the mixed field in order to leave the white exclusively on the face to form the rectangular figure. The equipment necessary to produce this is one tuck pressure alternating with a plain presser, which is the combination used in most figure designing when colors are used and even when they are not. Evidently this requires an even number of feeds, 2, 4, 6, 8, etc. *To reverse the colors at the feeds reverses the color of the figure but leaves the field unchanged, since both threads combine to form the field.*

Relation of Pattern Wheel and Yarn. — Since one color remains in the face all of the time, the plain presser operates immediately after that color is fed, as it does with plain fabric. Consequently, the tuck presser operates on the needles immediately after the feeding of the yarn which is sometimes thrown on the back of the fabric.

The use of colors is not necessary, since the contrast between the tuck and the plain stitches shows the design clearly enough for most purposes and sometimes more pleasingly than with the assistance of colors.

The effect produced in the fabric by the pattern is probably best called the design. *The design, like the pattern, is that portion of the fabric which entirely repeats itself.* It follows then that there are no fractional designs.

The design is composed of two parts, the figure, and its background, the field.

The main technical feature of figure design is the controlled disposition of the tucks in the field, which control embraces the size of the figure and of the field, the shape and position of the figure, and its relation to the top of the fabric.

Almost any knitter can make a design by filing nicks in a presser and putting it on the machine, just as almost any cook can make a cake by mixing flour, sugar, eggs and baking powder and putting the mixture in the oven. But it takes a fairly good knitter to nick the presser so as to obtain the exact design desired, just as it takes a fairly good cook to mix batter which will turn out a predetermined kind of cake.

Learning to Design. — The object of this discussion is to enable the knitter to know how to nick the presser in order to have the design come out just as he desires, instead of upside down, backward or entirely different from that which he had planned. It is exact knowledge such as this which the knitter needs, and it cannot be obtained without a certain amount of mental effort. However, if that effort is well directed, the subject should be learned readily and retained permanently. Both of these objects may be accomplished by learning first how to work out the principles; second, by learning the principles; and last, by learning the application of them; and then remembering these divisions in the same order. The application of the principles involves the most details and so is easily forgotten; moreover, even when remembered, the necessity for use may be on some unfamiliar type of machine, so the principles themselves will be needed in order to work out the application. Consequently, the principles are the essentials, but disuse may cause even them to be forgotten. However, if the method of deriving the principles is remembered, then whenever any question regarding figure design arises, the knitter can without books or assistance start right at the bottom and derive not only the principles but the application of them to any machine. The subject is developed in line with the above suggestions, by establishing unmistakable terms, by using the analogy of the printing wheel on the ribbon, and by gradually introducing the variations which may be produced with the fixed pattern.

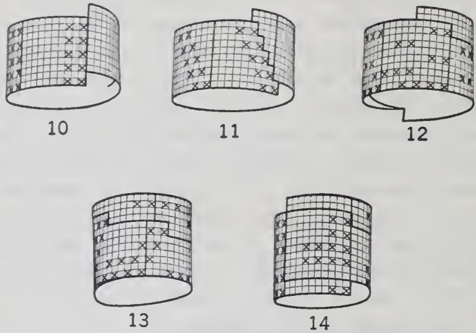
The size of the design is measured in stitches, since this unit has a fixed connection with the needles, whereas any other unit has not.

Consider that from a piece of fabric knit with two feeds — one, tuck, and the other, plain — the following pattern is obtained by copying a tuck course until repetition of the pattern begins:

o o o o o o o o o o o o o x o x o x o x o o o x o x o x o x o o o o o o o x o x o o o o o o o x o x

The ciphers represent plain stitches and the cross-marks indicate tuck stitches, showing altogether fifty needles in the pattern. It is desired to know what designs are possible with this pattern.

Winding Strip Pattern to Make the Design. — If the abovementioned pattern is repeated several times on a long strip of paper equally divided in spaces corresponding to needles, and then this piece of paper is wound helically to form a tube, the cross marks will show different figures according to the diameter of the tube, among which figures will be those shown in Illustrations 10, 11, 12, 13, 14. But it is somewhat difficult to arrange and hold such a long strip, so a substitute may be made for No. 10, say, by copying the 50-needle pattern on cross-section paper so that the same needles fall in the same vertical lines, as



Models of tubular pattern fabrics. The designs are such as are obtainable with the pattern shown in 20 by change in the number of needles and the direction of motion of the machine. The results could be duplicated practically with a two-feed machine, one feed having a tuck presser cut like one row of 20 and the other feed having a plain presser. The models are not shown for Nos. 25 to 30 inclusive.

No. 10. Vertical stripes caused by the use of a number of needles equal to a multiple of the pattern. The fabric motion is right-hand. No. 20 is the development of No. 10, and would be unchanged for left-hand motion.

No. 11. Inclined stripes caused by the use of slight overlap (needles one less than a multiple of the pattern). The motion is right-hand. No. 21 is the development.

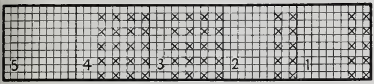
No. 12. Stripes inclined diagonally in two directions, caused by the use of overlap of half a pattern division (needles five less than a multiple of the pattern). The motion is right-hand. No. 22 is the development.

No. 13. Inclined figure caused by the use of a number of needles nearly one pattern division less than a multiple of the pattern (needles nine less — the division is ten). No. 23 is the development.

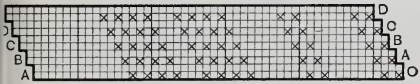
No. 14. Vertical figure caused by the use of a number of needles one division less than a multiple of pattern (needles ten less). The motion is right-hand. No. 24 is the development. Notice that the front of the pattern, indicated by the double tuck, is uppermost.

in Illustration 20. If this is cut out and the ends are curved to meet, the stripes will be just like those in Illustration 10. Evidently, there are 50 needles in the circumference the same as in the pattern. From this comes the conclusion that when the number of needles in the cylinder is the same as the number in the pattern the design consists of vertical stripes. Now it is evident that two strips just like Illustration 20 might be pieced end to end, or three or any number, and still the design would be vertical stripes, from which comes the conclusion that *when* *the pattern divides the needles integrally the design consists of vertical repetitions of the elements of the pattern.*

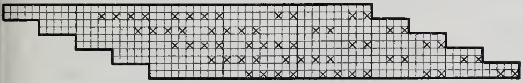
Development. — When a tubular figure is cut lengthwise and spread out, it is called the development of the original figure. Consequently, Illustration 20 is the development of Illustration 10, also 21 is the development of 11 and so on, each development



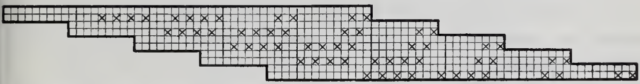
20



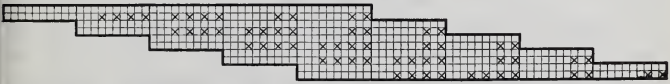
21



22



23



24

No. 20. Development of No. 10. No. 21. Development of No. 11.
No. 22. Development of No. 12. No. 23. Development of No. 13.
No. 24. Development of No. 14.

being designated by the number which is ten greater than that of the figure.

Decreasing the Number of Needles in the Cylinder. — Considering Illustration 21 the observer will notice that it is made by repeating the pattern over itself, but that each repetition starting from the lower right corner is one needle to the left of that above it, so that the ends have a step-like appearance. If the piece of paper is cut out and the ends are matched so that the double courses marked *A*, *B*, *C*, *D* meet, then development 21 will be like tube 11, *but the distance around the tube will be only* 49 *needles, which is one less than the number in the pattern.* Evidently, the vertical stripes are tipped with the bottoms to the right, in which direction the fabric is supposed to be moving, since the double course marked 0 is free, as if the yarn were raveled to that point. If other pieces like 21 but with 50 needles were put end to end with 21, and formed into a tube with corresponding terminal courses meeting as they do in Illustration 21, then the number of needles might be 99, 149, 199, etc., always 1 less than a whole number of patterns, and the inclination would be the same as in 21, which shows that when the number of needles is one less than an exact multiple of the pattern, the upper end of the vertical stripes falls back from the direction of motion of the fabric. That is, the front part of the pattern falls back over the front part of the pattern previously knit, or overlaps it.

Development 22 has five needles less than the pattern, and it will be noticed that the inclination has gone so far that the stripes begin to mix.

Development 23 has 9 needles less than the pattern and it is evident that a figure is beginning to form from the gathering together of one element from each stripe with the front of the pattern uppermost.

Condition for Desired Design. — Development 24 has 10 needles less than the pattern and shows the figure completely formed. In this the pattern may be read horizontally to the left along the courses, or vertically down the wales. This is the result generally sought in figure designing — that is, one in which the pattern or horizontal portion is repeated vertically in the figure. To obtain this, the pattern is divided into sections of equal length, and the impressions in each section, or division, are arranged with some sort of symmetry about the middle of the division. It will be noticed that division 5 is blank. This is to make a break in the vertical effect, which would otherwise still be a vertical stripe (although an irregular one) since it is made up of portions of each division of the pattern.

Reversing Motion. — Now consider the machine to contain 50, or 100, or 150 needles making vertical stripes, except that it turns in the *opposite direction* so that the fabric moves to the left side instead of to the right. Note, however, that since it is agreed to call the part of the pattern which first makes its impression the front, the beginning of the pattern is now on the left instead of on the right. In other words, when the motion is reversed, the front of the pattern is also reversed. Evidently, with the number of needles just given the effect in the fabric will be vertical lines as before, so that Illustration 20 will still represent the development.

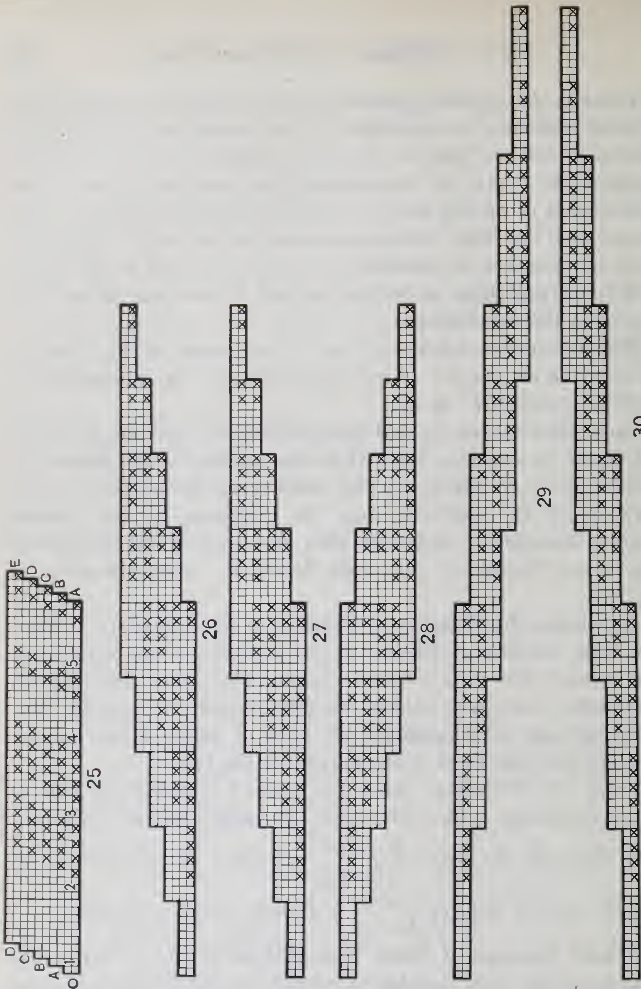
For one needle taken out, the development is like that in Illustration 25, and for 10 needles taken out, the development is like that in Illustration 26.

From Illustrations 24 and 26 it follows as it did for motion in the opposite direction that when the number of needles in the cylinder fails to divide by the number in the pattern by one division of the pattern, then the divisions of the pattern arrange themselves vertically with the front of the division at the top. Therefore, one rule holds for each direction of motion.

Increasing the Number of Needles in the Cylinder. — When the total number of needles in the cylinder is one division of the pattern *more* than a whole number of patterns, the result for right-hand motion is shown by Illustration 27, and for left-hand motion, by Illustration 28, both of which show that the front of the pattern is at the bottom of the figure.

From the preceding comes the general fundamental rule of figure designing. *The divisions of the pattern arrange themselves vertically with the front* $\begin{pmatrix}\textit{upward}\\ \textit{downward}\end{pmatrix}$ *when the needles in the cylinder are one division* $\begin{pmatrix}\textit{under}\\ \textit{over}\end{pmatrix}$ *a whole number of patterns.*

Needle Changes of More than One Division. — So far, the change in the total number of needles in the cylinder has not been more than one section — that is, 10 needles — from an equal division by the pattern. If the change extends beyond one division of needles, the figure inclines and reforms into *two figures* when the discrepancy from an equal division by the pattern is *two divisions*, as it is seen for right-hand motion in Illustration 29 for needles two divisions less than one pattern, and in Illustration 30 for needles two divisions more than one pattern.



No. 25. Development of a model such as No. 11 would be with left-hand motion. Comparison with 21 shows that reversal of the motion reverses the initial inclination of the stripes.

No. 26. Development of a model such as No. 14 would be with left-hand motion. Comparison with 14 and 24 shows that *reversal of the direction of motion inverts the figure about a horizontal axis in its plane.*

No. 27. Development of a model such as No. 14 would be for needles one division *more* than a multiple of the pattern and for right-hand motion.

No. 28. Same as No. 27, but for left-hand motion. Comparisons of 24 with 28 and of 26 with 27 show that reversal of both the lap and the direction of motion leaves the figure undisturbed.

No. 29. Development obtained by the use of a number of needles two divisions less than a multiple of the pattern and right-hand motion. Notice the division of the pattern into two figures instead of one.

No. 30. Development obtained by the use of a number of needles two divisions more than a multiple of the pattern and right-hand motion. Notice the division of the pattern into two figures instead of one.

Advantages of Paper Strip Method. — The above method of connecting the pattern and the design should be remembered, for it affords a convenient way of working from the design right back to the tube of fabric with the direction of motion and needle relation clearly shown. Indeed, this method is preferable to working exclusively on the machine, since machines are restricted to a narrow range of variation, whereas this paper method is subject to all of the variations possible; moreover, it is graphical, even to the duplication of an equivalent tube, and best of all, it proves what will be obtained, whereas the ordinary method of drawing the figure in a rectangle is not susceptible of proof that the result in the fabric will be as it appears in the plan.

The variations due to more extensive overlap may also be shown by this method, but they are more readily shown by the following one which is substantially an abbreviation of the one just given, and is advantageous in that it is much quicker, and does not require cross-section paper. It does not, however, show the slight variations obtainable by a change of needles between whole divisions of the pattern.

Numerical Method

For convenience consider a pattern having five divisions of ten needles each, just such as has been used. The width of the pattern may be any number of feeds. Number these divisions 1, 2, 3, 4, 5, beginning with the one which first makes its impression. Suppose that the machine has ten needles, which is one division. Then the first division will just finish the first revolution, the second division will just finish the second revolution, etc., so that if the fabric is cut lengthwise between the first and the tenth needle, it will show the pattern in the numerical order of its divisions with number one at the bottom: Illustration 32.

Now, consider that the machine has 20 needles, which is two divisions. Then the first revolution will take the first two divisions, the second revolution will take the third and fourth divisions, and the third revolution will take the last division and the first one over again in order to fill up. Consequently, when the tube is cut open and flattened out, the different divisions will appear on it as in Illustration 33. It is evident that four straight lines will not bound this design, but that six are required. The reason for this is clearly that the number of divisions in the pattern is not evenly divisible by two, the number of divisions of lap. In each of these cases, and in those that immediately follow, the flattened piece of fabric is a development of the tube, with the division following a wale, instead of following the end of the pattern as it is shown in Illustrations 21 to 24. It is noticeable that when there is one division of needles there is only one design of one figure; but when there are two divisions, there are two designs each composed of two figures.

Now consider the machine to contain three divisions of needles, that is, 30. The fabric appears like Illustration 34. Evidently, there are three different designs, each composed of three groups of figures.

For four divisions of needles there are really four different designs, as Illustration 35 indicates; but they all look like Illustration 32, except that now division 1 is at the top instead of at the bottom.

Of course, when the machine contains five divisions of needles, the fabric shows vertical stripes corresponding to each section as Illustration 20 shows.

For six divisions of needles, Illustration 36, the fabric shows just what it did for one division. This may be seen by a comparison of 36 and 32 which are put close together for the purpose.

Range of Designs. — Moreover, it will be found that all of the *vertical* figures obtainable with any number of needles are shown by the changes between one division and the total number of divisions in the pattern. Of course, the inclination of the stripes is not shown within that range, since all of the stripes do not appear until the number of needles in the cylinder is equal to the number of needles in the pattern. But one more division is enough to give all of the inclinations of the stripes. Moreover, a conglomeration is obtainable with a number of needles less than one division. So, *in general, all obtainable designs including all elements of the pattern are embraced by a range of needles from zero to one division more than the length of the pattern.*

Real and Apparent Design. — Before going farther with the above understanding of the word design, it is necessary to distinguish the real from the apparent design. Take Illustration 33 for instance. It shows two designs, each with two figures, of which one is the reverse of the other. Now refer to 37 which is the same as 33, except that the piece of fabric is larger, and affords a more comprehensive view of the designs. Reading

Numerical Diagrams

For explanation see Numerical Method, page 223.

32.

5
4
3
2
1

Arrangement of pattern divisions in the fabric when the number of needles is just one pattern division.

4	3	2	1	5	4
3	2	1	5	4	3
2	1	5	4	3	2
1	5	4	3	2	1
5	4	3	2	1	5
4	3	2	1	5	4
3	2	1	5	4	3
2	1	5	4	3	2
1	5	4	3	2	1

36. Ditto six pattern divisions.

33.

5	4
3	2
1	5
4	3
2	1

Arrangement of pattern divisions when the number of needles in the cylinder is two pattern divisions.

3	2	1	5	4	3	2
1	5	4	3	2	1	5
4	3	2	1	5	4	3
2	1	5	4	3	2	1
5	4	3	2	1	5	4
3	2	1	5	4	3	2
1	5	4	3	2	1	5
4	3	2	1	5	4	3
2	1	5	4	3	2	1

37. Ditto seven pattern divisions.

34.

5	4	3
2	1	5
4	3	2
1	5	4
3	2	1

Arrangement of pattern divisions when the number of needles in the cylinder is three pattern divisions.

2	1	5	4	3	2	1	5
4	3	2	1	5	4	3	2
1	5	4	3	2	1	5	4
3	2	1	5	4	3	2	1
5	4	3	2	1	5	4	3
2	1	5	4	3	2	1	5
4	3	2	1	5	4	3	2
1	5	4	3	2	1	5	4
3	2	1	5	4	3	2	1

38. Ditto eight pattern divisions.

35.

5	4	3	2
1	5	4	3
2	1	5	4
3	2	1	5
4	3	2	1

Ditto four pattern divisions.

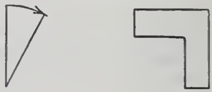
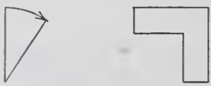
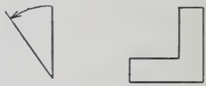
1	5	4	3	2	1	5	4	3
2	1	5	4	3	2	1	5	4
3	2	1	5	4	3	2	1	5
4	3	2	1	5	4	3	2	1
5	4	3	2	1	5	4	3	2
1	5	4	3	2	1	5	4	3
2	1	5	4	3	2	1	5	4
3	2	1	5	4	3	2	1	5
4	3	2	1	5	4	3	2	1

39. Ditto nine pattern divisions.

Illustrations 32 to 39, inclusive.

the numbers upward in vertical columns, one sees that the grouping 24135 constantly repeats itself over the whole extent of the fabric. Consequently, this apparent design fills the condition for a design, namely, that it is an effect which entirely repeats itself. In short, as far as appearances are concerned, there is but one single figure design for each case in which the number of needles is a multiple of the pattern division. Illustration 38 shows this for Illustration 34, as does 39 for 35.

Key to Illustrations 11 to 28, Inclusive

	Right-hand Motion	Left-hand Motion
Overlap. Needle remainder less than a whole number of patterns.	 Illustrations 11,12,13,14, 21,22,23,24	 Illustrations 25,26
Underlap. Remainder more than a whole number of patterns.	 Illustration 27	 Illustration 28

The direction of motion and lap is shown on the upper and left margins of the table.

The diagram in the right corner of the squares is recognized as the diagram produced by the given pattern. The position of the diagram is for lap of one division according to the direction of lap and the direction of motion given.

The diagram in the left corner of the squares shows how the vertical lines start to incline when a slight change in the direction of lap is made from an equal division of cylinder needles by the pattern.

It is evident that whereas a change of either direction of lap or direction of motion reverses the position of the design about a horizontal axis, the change of both together leaves the design undisturbed.

Inclination of Designs. — It is evident, however, that the relative arrangement of these apparent designs is different for each change of needles amounting to a pattern division. For one division, or six divisions, or eleven divisions, etc., each, the design rises to the right above the preceding one by the width of the pattern (for right-hand motion of the fabric). But when the number of needles is two divisions, seven divisions, twelve divisions, etc., the direction of inclination is the opposite and the second rises two widths above the first, and so on. Illustrations from 36 to 39 inclusive show the relative arrangements of the apparent designs for five section patterns. It is unnecessary to try to remember these relations, or even the groupings. But it is advisable to remember the method, for then all of this information may be quickly obtained when needed, and without the necessity of sketching the actual design. This method affords a convenient way of telling what the design will be for a lap of any number of divisions.

It will be recalled that the width of the strip pattern may be any number of feeds. But a certain length was taken, namely five divisions of 10 needles each, which length has not changed. Therefore, if one tuck feed is used, the design will be five tuck courses high; if two feeds are used, the design will be ten tuck courses high; and *in general the height of the design in tuck courses will be the number of tuck feeds multiplied by the number of divisions.*

Design Calculations

The mathematical part of figure designing is the big stumbling block to learning how to design from books. However, the calculations in connection with figure designing are very simple, as the following explanation will show.

There are four points to consider, namely:

The number of needles in the cylinder.
The width of the design (horizontally).
The length of the pattern.
The height of the design.

Evidently, the easiest way to consider them is one at a time. *The number of needles in the cylinder.* A change in this number of one or two per cent is allowable in leaded spring-needle machines; but other machines are changeable only by the substitution of a new cylinder, which is expensive and troublesome. Consequently, it is generally necessary to adapt the design to the number of needles in the machine, and it is advisable to do so even in the case of leaded-needle machines, since changing to a certain number of needles and retaining that number is somewhat troublesome. Many users of knitting machinery facilitate the manufacture of pattern fabric by having their machines made originally with a suitable number of needles in each cylinder. (It will be shown later what numbers are suitable.) Since, then, the number of needles in the cylinder is sometimes practically unchangeable, and at others changeable only inconveniently, this number is the basis of the calculations. Therefore, given designs should be modified accordingly, or new designs should be made accordingly. The numbers of needles in different cylinders are generally known to the man who makes or modifies the design, or may be procured from the manufacturers of the machines if the machines are not where the needles may be counted. This book gives the numbers of needles for some types of machine.

Illustration 40 will help the balance of the explanation. Diagram *A* 1 shows a developed needle line — that is, the circular needle line cut open and spread out straight. It might contain any number of needles, but here for convenience it contains 65, each one represented by a vertical space.

The Width of the Design. — This must divide into the number of needles in the cylinder, that is, into 65 in this case. If the number of needles in the cylinder is not divisible, that is, if the number is a prime number, then vertical figures cannot be made. Diagonal effects may be produced, but they are not considered in this discussion. Therefore, if the number of cylinder needles is not divisible, the cylinder is not usable for this kind of designing. But in this case the number is divisible, since 65 may be divided by 5 and by 13. These are the only widths of pattern usable, since they are the only divisors of the number of needles. For illustration select 5, since the paper is laid off in groups of five. Then 5 is the pattern division, since it not only has to divide into the number of needles but also into the pattern, as will be shown later. Moreover, it is more convenient to continue the discussion with divisions as the measure, instead of needles, just as it is more convenient to discuss fortunes in thousands of dollars instead of dollars or cents, both of which are such small units that the figures would be cumbersome.

There are 13 divisions in the cylinder, since 5 divides into 65 thirteen times.

The Length of the Pattern. — Now it has been repeatedly shown that the pattern must not divide evenly into the number

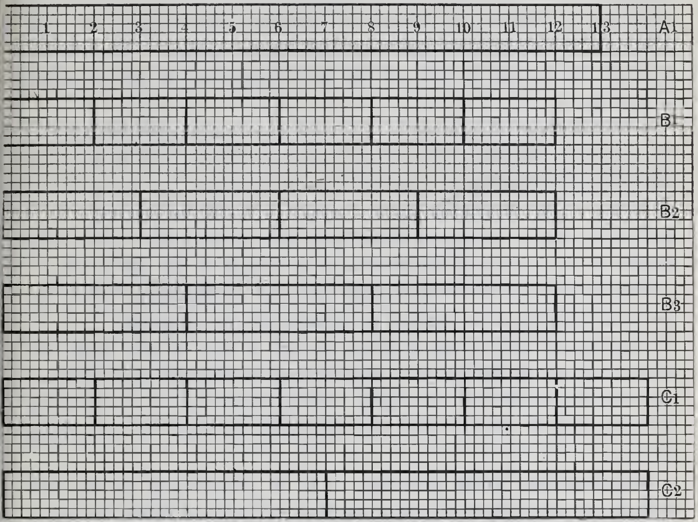


Illustration 40.

A1 represents a developed needle line containing 65 needles. The other strips show the total pattern lengths and divisions usable with 65 needles. B1, B2, B3 are for underlap. C1, C2 are for overlap.

of needles by one division. Therefore, the pattern must divide into 12 divisions, or into 14 divisions, which numbers are one less and one more than the number of divisions in the cylinder. Diagrams *B*1, *B*2 and *B*3 contain 12 divisions, and diagrams *C*1 and *C*2 contain 14 divisions. The principal use of these diagrams is to make clear this step of the calculations, which is the confusing one to the student. It should be thoroughly understood, that the number of needles is not changed by one division. These lengths *B* and *C* are taken merely for the purpose of determining what length of pattern is permissible. The reason for taking them is at once apparent; for, evidently, if the pattern divides these lengths *without* a remainder, then it must divide the number of needles *with* a remainder of just one division, or one design width, which is the condition to be met.

The *B* diagrams show that the usual patterns for underlap may be 2, 3 or 4 divisions in length. The *C* diagrams show that the usable patterns for overlap may be 2 or 7 divisions in length. The inversion of the design caused by change from overlap to underlap is shown by Illustrations 24 and 27, and is stated in the general rule for tuck figure design. This inversion of the design is one of the considerations in the selection of the lap.

The Height of the Design. — This is the other consideration in the choice of the lap. It is expressed in courses and equals the number of divisions of the pattern multiplied by the number of feeds. The diagrams show a range of patterns having 2, 3, 4 and 7 divisions. Suppose four feeds are to be used. Then the height of the design in courses may be either 8, 12, 16 or 28.

This is all there is to customary pattern calculations, when the work is based on the number of needles in the cylinder.

Copying or modifying a given design is one of the most important parts of the subject, and it may be explained by following through all of the processes. First, however, it is advisable to understand clearly the conventional method of sketching designs.

Representing Tuck Stitches. — It is customary to lay out designs on cross-section paper, so that horizontal rows represent courses and vertical rows represent wales. When the squares contain no crosses, the diagram represents plain fabric. Then the individual squares represent loops of plain fabric. They are frequently considered to represent stitches, but since a stitch is a combination of at least two loops, this practice causes confusion when it is necessary to reconcile the diagram with the fabric which it represents. It should be thoroughly understood, therefore, that before any crosses are made on the diagram the squares represent loops of plain fabric, and when a cross is put in a square it means that what would have been a loop of plain fabric is changed to a tuck portion of pattern fabric. This cross does not make the diagram look like the fabric which it represents, for several reasons. The tuck loop remains on the back of the fabric, whereas the face is viewed. The loop which does appear on the face is the held loop which belongs in the next square below if single tuck, and in the second square below if double tuck. The cross would seem to indicate that the loop in that position is more prominent than the others, just as the conventional sketches of tuck stitches do, but in reality the loops alongside of the marked one are frequently larger. And finally, the stresses caused by the tucking pull the wales and courses out of the positions which they would occupy in plain fabric. Consequently, the only way for the novice to see the diagram in the fabric is to see a tuck loop represented by the cross, in the place of a corresponding plain loop of plain fabric. At first it may be necessary to turn the fabric over in order to make sure that the tuck loop is there. Inspection against the light frequently shows the tuck loop like a broad arrow head pointing upward. The student should learn to look at fabric in many different positions and in many different lights, for it takes thorough acquaintance to prepare one for understanding the puzzling combinations which are possible.

Showing Plain and Tuck Courses in Diagram. — It is customary to omit the plain courses from the diagrams, for several good reasons, such as to save time and space, and probably best of all to contract the diagram vertically by omission of the plain courses so that it is nearly proportional to the result in the fabric, which is reduced vertically by the narrowness of the courses with respect to the wales, and by the shortening and widening caused by the tucking. But in spite of these reasons it seems better, especially for the beginner, to show all courses in the diagram, because the true structural representation is more desirable than the exact appearance of the design; and because the method should not be restricted to a plain presser for every second feed, but should accommodate any combination of feeds, so that the knitter may not only be able to make novel designs but may be encouraged to do so. Accordingly, the diagrams used in this book show all courses, but it is to be understood that the design will appear in the fabric relatively shorter (vertically) than it is in the diagram. This distortion of the diagram may be obviated by using paper ruled with spaces about twice as wide as they are high.

Design Should not Begin and End with the Same Kind of Course. — A consideration which really belongs to the question of the number of needles is of so much importance that it is mentioned here also. Since the feeds are generally used in pairs, the height of the diagram must be an even number of courses; and since a tuck feed is followed by a plain feed, every diagram must begin with a tuck course and end with a plain course or vice versa. This arrangement of the feeds in pairs relieves the designer from remembering that the ending and beginning of the diagram must be with a different kind of presser in order to prevent the meeting of courses of the same kind

Illustration 41.

where the designs join. But it is advisable to bear this in mind when every other feed is not plain, or else double tucks may occur unintentionally at the joining of the designs.

Illustration 41 shows the face of a small piece of flat underwear fabric knit with a tuck figure design. The portion which came last from the needles is at the top.

Since this is a small piece of fabric, it is impossible to trace the pattern along the courses far enough to copy all of it; and since the shape is not tubular, it is impossible to determine the number of feeds by raveling the threads to one wale and counting them.

Analyzing Samples. — There are three ways in which this design may be duplicated. One way is to ravel as many courses as the design has courses, and to mark on cross-section paper each tuck stitch in the order in which it occurs. Another way, is to sketch out on cross-section paper a similar design of apparently the same width and height. The third, and probably most used method, is a combination of the two just mentioned, consisting of some raveling and counting assisted by judicious estimating.

The advantages of the third method are that it saves time, saves fabric — since frequently only a small piece is available, and often the preservation of that is desirable — and furthermore, it saves eye strain, since a stitch-by-stitch analysis is trying, especially if the fabric is fine.

So this method will be used for illustration. At first it is desirable to disburden the mind of thought of the direction of motion, the number of feeds, and everything but the determination of the dimensions of the design. The other details will introduce themselves in time for their consideration.

Recalling that most designs are made by arranging the pattern or the number of needles in the cylinder so that the ends of the pattern lap one division over or under, which makes the divisions read vertically in the same order in which they read horizontally in the pattern, we may assume that this design was made in that way. Then the boundary of the design will be four sided. The first step is to determine its width and height.

Determining the Width of the Design. — Consider the width first. It is evident that one vertical stripe is the duplicate of the others. Therefore, the width equals the number of wales from a point in one stripe to the corresponding point in the next stripe. The surest way to obtain this width is to ravel the rough top edge of the fabric — the bottom will not ravel — until it is sufficiently smooth and clear of lint to ravel freely all the way across. During this raveling it will be found that a plain feed followed a tuck feed in regular succession, consequently, the number of feeds must be even, that is 2, 4, 6, 8 etc. This information is needed for future reference. When the edge ravels freely, one course should be raveled slowly enough to count the wales from, say, the right side of one stripe to the right side of the next one. Provision should be made to guard against counting too far, since the tendency is to count from one tuck to the duplicate tuck inclusive, whereas if counting is started with one tuck it should extend *to* the duplicate tuck but should not include it.

Marking the Limiting Stitches. — When it is difficult to distinguish the beginning and the ending of the count, the wales may be selected before the counting is begun, and marked down their centers with a pen. Indeed, one of the fundamental qualifications for design analysis is efficiency. It is not unusual to see a sample of fabric raveled nearly away before the observer has learned anything definite about it. In order to avoid such mistakes, it is advisable to form the habit of making every move show for something. Starting and stopping places may be marked with a little ink in the loop of the selected stitches; or a pin may be put through each selected loop, and then the counting may be done between the pins on the sides where the heads are not, since the heads prevent counting close to the shank of the pin. During the raveling to ascertain the arrangement of the tucks, a starting wale should be selected, and marked with ink, and then the tucks should be recorded on cross-section paper in the order in which they occur. An attempt to remember the tuck arrangement is almost sure to result in confusion unless the observer is quite familiar with the work.

The width of the sample in question is found, by counting, to be 30 wales.

Determining the Height of the Design. — The height of the design is the number of courses from any point in a square to the corresponding point in the next square above or below. The starting and stopping points are sometimes not readily determined, since counting in the figured portion is confusing. To overcome this difficulty, it is sometimes permissible to cut from one side of the pattern a narrow strip of fabric, say five or six wales in width. Ravel this from a selected point in one square to the corresponding point in the next square below, counting the threads as they are raveled and keeping them together for checking the count after the raveling is finished.

The height of this design is found to be 24 courses. If the count had come out an odd number, it would obviously have been wrong, since it is known that an even number of feeds was used.

Two limitations of the number of feeds are now known, namely, that the number is even and that the number must divide evenly into 24, since each feed must make its impression in the design as many times as there are divisions in the pattern.

From this it is easy to make a table of the possible combinations of numbers of feeds and divisions of pattern, since the only fabric conditions are that the number of feeds be even and that the product of feeds and fabric divisions in the pattern be equal to 2

Table

Feeds		Divisions	Courses in design
2	×	12	= 24
4	×	6	
6	×	4	
8	×	3	
12	×	2	
24	×	1	

This table gives all the possible combinations of feeds, from which selection may be made according to convenience and to the facilities available, since any of these combinations will make the design. In other words, a design may generally be duplicated without duplication of the particular equipment with which it was produced. But it is frequently desirable to know how many feeds were actually used to produce the design in question. This is learned for one division lap by counting the difference in elevation in courses of two adjoining designs, as is seen by reference to Illustrations 36 and 39. Raveling from the top of one square to the top of the corresponding one in the next design shows a difference of 4 courses, consequently, four feeds were used to make the sample in question. Of course, if the pattern lap is more than one section, then the difference in the height of two adjoining designs would be a multiple of the number of feeds as in Illustrations 37 and 38, but that case is not the usual one so it is not considered here.

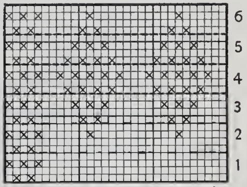


Illustration 42.
Diagram of the design shown in Illustration 41.

The Structure and Dimensions of the Figures. — The next step is the determination of the dimensions and structure of the figures. The raveling so far has shown that only single tucks are used, both vertically and horizontally, and that these are arranged diagonally with respect to each other. Moreover, close inspection, taken in consideration with the symmetrical arrangement of the figures and some stitch counting, shows the design to be as in Illustration 42.

Knitting Motion. — Since the direction of motion is not indicated by the sample, this also may be a matter of choice just as the number of feeds, if the inversion of the figure as in Illustration 26 compared with 24 is not objectionable. Table 1, on page 204, classifying machines by fabric motion facilitates adapting the motion to any particular type of machine. Suppose that the third type from the top of the table is selected, since this is a representative American type. Then, as the table shows, the fabric motion is right-hand. Consequently, the design illustrated in the sketch is to be produced in the fabric by motion toward the right.

Table 2, on page 235, of feeds and corresponding pattern sections shows a practical range of 4, 6 or 8 feeds, but inasmuch as the sample was apparently made with 4 feeds, the discussion may well be carried out with that number. Then according to the table, the number of divisions in the pattern must be six, which is also the number of divisions in the diagram.

Direction of Lap. — The next consideration is whether the lap is to be over or under. Evidently, if the pattern overlaps, the number of cylinder needles is one division less than a whole number of patterns, and if the pattern underlaps, the number of cylinder needles is one division over a whole number of patterns. That is, if the lap is *under*, the remainder is *over*, and vice versa. If this is not perfectly clear, one can make it so by forming a closed circle of a paper pattern with end margins, and then underlapping or overlapping the ends of the pattern. The sample was evidently made with underlap, so the needle remainder was one division over an integral number of patterns.

The following table gives the numbers of cylinder needles for producing this design with either overlap or underlap. The second number of the bracketed pair is for underlap and should be used for strict duplication of the design.

Referring to the diagram of the design, Illustration 42, and remembering that the motion of knitting is right-hand, the observer sees that the lower right corner of the design will be knit first. The rule is: The divisions of the pattern arrange

Table 3

(1)	(2)	(3)	(4)
Number of patterns	Number of patterns multiplied by the number of divisions in one pattern (1) × 6	Number of divisions in cylinder, (2) ± 1	Number of needles in cylinder, (3) × 30
0	0	1	30
1	6	5 7	150 210
2	12	11 13	330 390
3	18	17 19	510 570
4	24	23 25	690 750
5	30	29 31	870 930
6	36	35 37	1050 1110

themselves vertically with the front $\begin{pmatrix}\text{upward}\\ \text{downward}\end{pmatrix}$ when the needles in the cylinder are one division $\begin{pmatrix}\text{under}\\ \text{over}\end{pmatrix}$ a whole number of patterns. In order to avoid confusion this rule may be stated in terms of the lap for this case as follows: The divisions of the pattern arrange themselves vertically with the front $\begin{pmatrix}\text{upward}\\ \text{downward}\end{pmatrix}$ when the lap is one division $\begin{pmatrix}\text{over}\\ \text{under}\end{pmatrix}$. Therefore, for underlap the divisions of the pattern will repeat themselves vertically with the first one at the bottom. Consequently the design may be numbered upward on the right side, 1, 2, 3, 4, 5, 6, as it is shown, according to the six equal divisions of four feeds each, arranged in pairs with one tuck presser followed by a plain presser.

Inversion of Figures. — It is interesting to note in this connection that when the figures are symmetrical with respect to a horizontal axis, it generally matters little whether the lap is over or under. This design has figures which are symmetrical with respect to a horizontal axis, that is, these figures may be turned upside down without changing their appearance. Change in the direction of the lap inverts the design and changes the arrangement of the duplicate designs with respect to each other, as a comparison of Illustrations 36 and 39 shows; but this change in relation of the designs is much less noticeable than

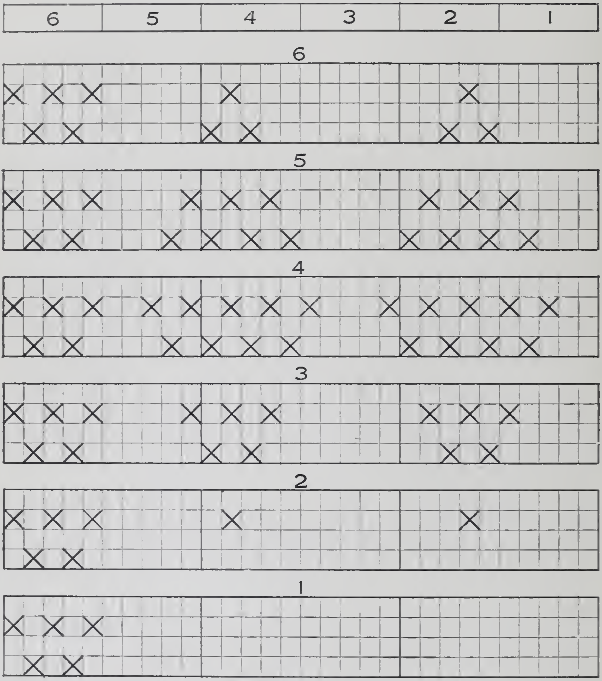


Illustration 43.
Strip pattern copied from Illustration 42.

the inversion of an unsymmetrical design, such as Illustration 24. Consequently, many designers use figures which may be inverted and pay no attention to the direction of the lap, since by neglecting it they double the available numbers of cylinder needles.

These divisions may be copied from Illustration 42 from left to right in the reverse of their numerical order on a strip of paper as shown in Illustration 43.

Proving the Pattern. — It is advisable to leave a margin at the top of the strip pattern, for this not only allows the numbering of the divisions without confusion of the numbers with the tuck crosses, but it provides a margin for coiling the strip in order to prove the accuracy of the design and its transference to the strip. Table 3, page 237, shows that the design is obtainable with 30 needles, so if this strip is coiled in a helix, so that the first needle of the pattern comes under the 31st needle, and so on to the end, the resulting tube will show the design just as it is in the diagram, provided the work has been properly done. It should be noted that this amounts to bringing division 2 over division 1, and that it is for underlap, which results from a number of needles one division more than an integral number of patterns. On the contrary, if the design needs overlap, which results from a number of needles one division less than an integral number of patterns, then division 6 must be brought over division 1 in order to prove the pattern by coiling it. This necessitates a much longer strip in order to show the whole design in the resulting tube.

After the strip pattern is proved, the next question is how to transfer it to the presser so that the design will not be reversed or inverted.

Forming the Presser from the Pattern. — Bring the ends of the strip together as in Illustration 44. This represents the edge of a printing wheel which will make the required design, for it is the right length, 180 needles, and it contains all of the required impressions in their proper order. *But* this wheel would have to run on the back of the fabric and print through to the face in order to make the design just as the sketch shows it. Some types of machine have the pressers placed so that this analogy holds. In this type the fabric runs downward, faces outward, revolves anti-clockwise and has the presser inside of the needle line. Consequently, for this type of machine Illustration 44 shows just how the pattern is to be put on the pressers, of which there are two, the first for the lower line of tucks and the second for the upper line of tucks. The first is to make the lowest course in the design; moreover the relative position of the pressers with respect to the needles which they press is to be just as it is shown in the strip pattern.

However, the most used types of machine are not like the type just described, for not the front but the back of the presser

Illustration 44.

Model presser formed from the pattern in Illustration 43 for duplication of the design in Illustration 41 for right-hand motion of fabric and front side of presser acting.

Illustration 45.

The same pattern as that in Illustration 44, but adapted by reversal to type 7 machine, Table 1, page 205.

operates to make the design. How can the pattern be adapted to them without the mistake of turning it end for end, or upside down?

Adapting the Pattern to Different Presser Positions. — Illustration 45 shows the strip pattern with its ends joined to form a circle, except that this time the strip is *inside out*. It is still *right side up* as it was at first. The pattern has been traced through on the back with the strip held against a window pane and the tuck crosses duplicated with a pencil on the back. The observer sees now by regarding the inside of the strip, that if this presser operates with the back side moving toward the right, the effect in the fabric will be just the same as before when the strip was right side out and the front side acted toward the right. Consequently, the pencil markings on the outside of the circular strip show how the pattern should be put on the presser when the back side operates on the needles.

As it was explained, there are two pressers, the pattern for each is on its respective tuck line, and the lower one knits first.

The circumference called for by the paper strip is 180 needles, but it may be 360, or any other multiple of 180, provided the pattern is duplicated all around the edge of the presser.

Suppose that the number of needles in the available cylinder is 957. This number is not suitable for a design 30 needles in width, since it is not in Table 3, page 237. Consequently, it is necessary to find what widths are possible with this number of cylinder needles, in order to modify the design to correspond to 957 needles and still to use four feeds.

To begin with, the width of the design must divide into the cylinder needles, so it is necessary to find what numbers will divide 957. This is simply factoring, which may be set down as follows:

$$\begin{array}{r|l} 3 & 957 \\ \hline 11 & 319 \\ \hline & 29 \end{array}$$

Evidently, 3, 11, 29, 33 (3×11) and 87 (3×29) are the low numbers which will divide 957, and the two numbers nearest to 30, the width of the sample, are 29 and 33.

Try 29, since it is the nearer to 30 — so near that if it is usable, the design may be adapted to it by the omission of one wale from the field between the two squares.

The way to try the number is to see if its pattern divisions are suitable. Six would be preferable, since the height of the design should be left as it is, if the width is not to be changed more than one needle, which is practically no change so far as appearance is concerned.

The width 29 is contained in 957 thirty-three times; that is, the number of cylinder divisions is 33. But the pattern itself must divide into the needles with a remainder of one division over or under, so to find the possible pattern lengths, factor 32 and 34 = (33 ± 1).

$$\begin{array}{r|l} 2 & 32 \\ 2 & 16 \\ 2 & 8 \\ 2 & 4 \\ & 2 \end{array} \qquad\qquad \begin{array}{r|l} 2 & 34 \\ & 17 \end{array}$$

Evidently, 2, 4, 8, 16, 17 are available factors, and the nearest number of divisions for the pattern is 8, which multiplied by the number of feeds, 4, equals 32 instead of the 24 courses desired. The field could be made higher by eight courses, but the squares could not be enlarged proportionately, since the design has been narrowed by one needle. Consequently, this solution is not so satisfactory as it should be.

Generally Advisable to Reduce the Extent of the Design. — However, the 33-needle design width is still available for investigation, since the sample design might be widened so much without objection. This width divides into 957 twenty-nine times, so 29 is the number of cylinder divisions. The pattern must divide into one more or one less divisions, so factor 28 and 30 equal to (29 ± 1) to find the possible pattern divisions

$$\begin{array}{r|l} 2 & 28 \\ 2 & 14 \\ & 7 \end{array} \qquad\qquad \begin{array}{r|l} 2 & 30 \\ 3 & 15 \\ & 5 \end{array}$$

Evidently, the number of pattern divisions may be 2, 3, 4, 5, 6, 7. This is a happy solution, for the height of the design may be left as it is by the use of 6 divisions in the pattern, or may be increased by four courses to correspond roughly to the increase in width due to the use of 33 needles instead of 30. As far as the appearance of the design is concerned it will probably be satisfactory to use the original number of divisions in the pattern, namely, 6. However, there are practical considerations which sometimes make it advisable to reduce the design whenever modification is necessary. One consideration is that it is frequently desirable to recut the original pressers, which may be done if the length of the pattern is reduced, for the old cuts may be turned off and the new ones may then be made on the same pressers. This is especially desirable where the mill is isolated from the knitting machine shop, or when it is inconvenient to wait to get the pressers recut to order.

Adapting a Design to a Range of Cylinder Sizes. — So far the discussion has been carried on principally with one machine in view. But designs for underwear should be adaptable to the range of sizes used in underwear manufacture, including the sizes from which sleeves and drawers are cut, since all parts of the suit should match. This involves making one design adaptable to different numbers of feeds as well as to different numbers of needles, since the numbers of feeds decrease, as well as the numbers of needles, with decrease in the diameter of the machine. However, the feeds do not change by rule, whereas the needles do. Knowledge of the particular machine in question is generally required in order to plan for the numbers of feeds. But evidently the numbers of needles should change according to the difference in the diameters of the machines.

Difference in Standards. — An inch difference in diameter corresponds to 3.14 inches difference in circumference. Accordingly, if the machines are 10 cut, the difference between sizes is 31 or 32 needles. Moreover, since the diameters are generally even inches, the numbers of needles in the cylinders should be multiples of 31.4; that is, a one-inch cylinder should have 31 or 32 needles; a two-inch machine should have 62, 63 or 64 needles, etc. Consequently, for 10 cut, as a general rule, 31 or 32 might be adopted as a convenient design width. There are local qualifications to be looked for, such as difference between the nominal diameter and the actual diameter. For instance, in America two types of spring-needle loop-wheel machines are made with the nominal diameter of the machine the same as the actual diameter of the needle line, whereas another type has the needle line diameter approximately half an inch greater. Furthermore, one of the types in which the nominal and actual diameter agree has about one and one-half per cent less needles per inch than the nominal gauge. While it is not to be expected that the knitter should learn all these differences, and much less to be expected that he should remember them, still it is highly important to remember that such differences do exist, in order to learn the particular ones involved and to allow for them in a design for a range of sizes.

Cutting Cylinders in View of Pattern Work. — Manufacturers who have made pattern work in the past and contemplate making it in the future generally ascertain from the knitting machine maker what the difference is in needles between the cylinder sizes, and then have this difference or an average of it adopted as a divisor of all the cylinders. In order to do this, the cylinder diameters may have to be changed slightly so as to keep the cut standard.

So far, the discussion has involved comparatively long patterns and the use of plain pressers to clear the tucks, since the principles of designing are more readily explained under those conditions.

But much pattern work is done with short patterns and all tuck pressers. These conditions do not change the principles, but they require some attention which is not required with plain pressers.

Self-clearing Pressers. — Consider a knitting machine which has 100 needles and 1 feed with a plain presser just the diameter of the machine. This machine will make plain fabric. Put 100 slight notches — prints, they are called — equally spaced around the presser. Then the machine will still make plain fabric, but the presser will make one complete revolution every time the cylinder does. If it did not contain the prints it would slip back like a belt on a driving pulley. Now cut every second print deeper, so that it will not touch its corresponding needle. The machine will begin to make one-and-one tuck, or properly, tuck-one-knit-one fabric. But the tuck loops will continue to accumulate on every other needle, for they cannot be cleared, since the same deep cut comes opposite the same needle every time. However, if it could be arranged so that the loop on any needle would be tucked in one course and cleared in the next course, then the machine would work satisfactorily. Evidently, this would be accomplished if the needle which is visited by a cut in one course be visited by a print in the next course; and the way to accomplish this is to arrange that the presser will gain or lose one needle in each revolution of the cylinder, which might be done in two ways, either by changing the number of cylinder needles by one, or by changing the number of presser prints by one.

Consider changing the number of cylinder needles by adding one. Then the presser will fall back by one needle at each revolution, so at each succeeding course the needles which were tucked will be pressed, which was the condition required for successful operation of the machine. Evidently, the tucks will fall in diagonal lines, the lower ends of which will point back from the direction of knitting motion, as already explained. If a needle had been taken out, the lower end of the diagonal would point in the direction of knitting motion.

Improper Pressers. — Now, consider leaving 100 needles in the cylinder as at first and changing the number of needles in the presser by taking out one. This will leave 99 needles in the presser, which is an odd number, but the length of the pattern is two needles which is an even number, and since the presser must contain a whole number of patterns, the change cannot be made without violation of both the rule and the pattern. But suppose they are violated. What will happen? As to the presser, either one cut or one print has been omitted. If a cut has been omitted, two prints come alongside; and if a print has been omitted, two cuts come alongside. This causes somewhere among the single-tuck diagonals a stripe two plain stitches in width, or a stripe two tucks in width according to whether two prints come together or two cuts. One such diagonal in the whole circumference of the presser might not be objectionable, so this trick is frequently useful. It is not restricted to one-and-one work, but may be used with more extensive patterns. However, it is sometimes deceptive unless carefully used. This may be illustrated as follows.

Clearing by Changing the Needles. — Start with the original tuck arrangement, namely, a one-feed 100-needle machine with a one-and-one tuck presser 100 needles around. This is inoperative because it will not clear the tucks. Make the needles in the cylinder odd, say 99 or 101. Then the tucks will be cleared, and the machine will operate. Now, make the number of needles in the cylinder any other odd number, 201 or 355 or 931. The machine will still operate. Of course, any even number of needles would make the machine inoperative as with the original 100.

Clearing by Changing the Presser. — On the other hand, start with the 100-needle one-feed machine with a one-and-one tuck presser 100 needles in circumference, and consider changing the size of the presser as it has been explained, and using larger cylinders also. It was seen that the presser might be reduced by a print or a cut and that the machine would be operative, with a slight defect in the design. Now, suppose that the number of cylinder needles is increased to, say, 200. The number of needles in the presser divides into 200 with a remainder of 2, consequently, the tuck stitches would not be cleared, and the machine would load up. A moment's reflection will show the limitations of this method of using an odd number of cuts in a presser with an even pattern. The object of the method is to get a lap of one needle when the number of needles is even. But if the presser laps an even number of needles for one cylinder revolution, then it acts just like a single presser so many times bigger with an *even* number of cuts, consequently, the needles will load up, since the same needles will be pressed all the time.

Several Self-clearing Pressers. — It has just been shown that with a single feed and a tuck presser, the latter must clear its own tucks by pressing the needles which were skipped in the preceding course. But in a two-feed machine with two tuck pressers, evidently, one presser may clear the single tucks of the other, or each may clear its own loop, held over two courses. The following will make this clear. Since there are two feeds, the opportunity to lap comes only at every second course, as it is shown by the analogy of the printing wheel, in which all the pressers act as one single wheel. Now, entirely regardless of the lap these two pressers may be arranged in two ways with respect to each other; so that one clears the tucks of the other; or so that both tuck on the same needles. If one clears the tucks of the other, then the machine will operate regardless of the number of needles in the cylinder, because one presser takes care of the other; but if the second presser adds tucks where the first made them, then the clearing of these tucks must be

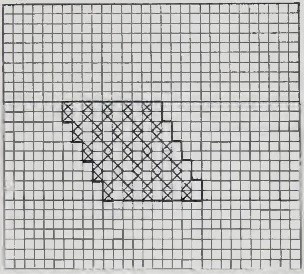
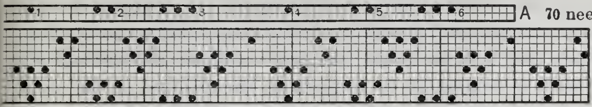


Illustration 46.

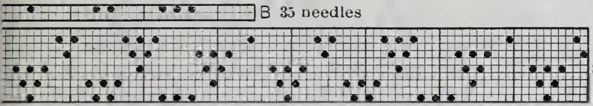
Diagram of one-and-one double tuck diagonals made with two tuck pressers which clear their tucks by lap instead of clearing them by a plain presser.

done with lap, which will make both pressers step ahead or back by an equal amount. It is advisable to get this principle firmly fixed, because it is applicable for as many feeds as the number of tucks allowable on one needle, say 6. Illustration 46 shows a diagram for a machine having two feeds, each with a one-and-one tuck presser, and arranged to tuck the same needles and then lap one needle at the second course in order to clear the double tucks.



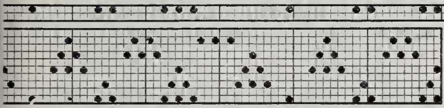
A 70 needles

47 80 needles



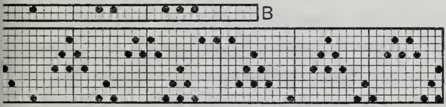
B 35 needles

48 80 needles



A 70 needles

49 60 needles



B

50 60 needles

Illustrations 47, 48, 49, and 50.

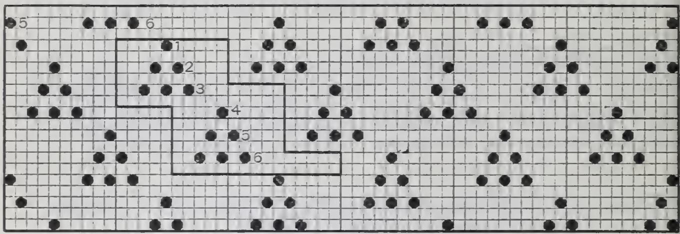
Exception to the general rule for patterns. Pattern **A** calls for a 70-needle presser according to the rule, but the design may also be made with **B**, which is a 35-needle presser.

Another arrangement which is frequently used is a modification of the one in which every second feed is plain, but instead of making every second feed plain, every third feed; say, is made plain, or possibly one feed of the whole lot. This feed clears all tucks which are not cleared ahead of it.

An Exception to the Rule for Pattern Lap. — After learning a rule one of the next important things to learn is the exceptions to it, since rarely is a rule so complete as to cover every case to which it is supposed to apply.

The rule that the number of needles in the cylinder must be a multiple of the number of needles in the pattern plus or minus one division of the pattern has exceptions which are likely to be puzzling when encountered unexpectedly, as the following case shows.

Illustration 47 is a design in which the inverted triangles are 10 needles apart, and which is apparently made with pattern divisions of 10 needles each. This design does not lend itself to analysis by the quadrangular method. If the sample is sufficiently wide to include 70 needles the pattern may be copied from the courses and will be found like that at *A* in Illustration 47. This pattern is suggestive of something exceptional to the rule,



51
Illustration.

Disposition of the elements of the 70-needle strip pattern **A** (above Illustration 47) when used with a 60-needle cylinder. The 35-needle strip pattern **B** (above Illustration 50) would make sections 1, 2, and 3, after which it would repeat them.

since it fills the condition for two patterns, namely repetition of the same characteristics; also the tucks are arranged in two groups of 1, 2, 3 each and the separation in the groups is 10 needles whereas between the groups it is 15 needles. To sum up, although the design seems to call for a shorter pattern than that shown, namely 70 needles, still there is no way to use a shorter pattern and to comply with the rule that the lap of the pattern shall be one pattern division, namely 10 needles.

In fact the rule applies because the design may be reproduced with pattern *A* on a cylinder with 80 needles, as shown in Illustration 47, or with 60 needles, as shown in Illustration 49, in which case, however, the triangle is no longer inverted, which is to be expected, for it was shown that reversal of the direction of lap inverts the figure about a horizontal axis in its plane. However, conformity to the rule is not proof that a shorter pattern is not usable.

In an actual case like this it was found that a 70-needle presser was too large for use, which indicated that a smaller presser had been used in making the sample. Accordingly the pattern was divided as *B* shows, and was found to meet the requirements of the design as Illustrations 48 and 50 show, although pattern *B* does not meet the requirements of the rule.

If the six divisions of pattern *A* are numbered 1, 2, 3, 4, 5, 6, and the divisions in the design are identified by these numbers, the boundary of the design will be found to be a ten-sided figure as Illustration 51 shows. When pattern *B* is used the boundary is a six-sided figure containing the divisions 1, 2, 3.

ECONOMICS OF KNITTING

The highest economy consists in the conversion of yarn into fabric at the lowest cost. Defects and waste must, of course, be included in the cost. Therefore, the subject embraces the factors which affect the cost of knitting.

A rough primary division of these considerations may be made as follows:

The space (including power).
The machine.
The yarn.
The operator.

Space. — The space cost can be affected but little except by change in the rate of production. If the rate is doubled without increase in the space, the space cost, per pound of fabric, say, is halved. Extra power will be required, but the increase in space cost due to increase in power cost is generally negligible. On the other hand, the characteristics of the space have much to do with the cost of knitting, since the efficiency of the machine is largely dependent on the physical and mental condition of the operator, which in turn is dependent not only on the light, temperature, ventilation, etc., of the surroundings, but on the character of the supervision. A hydro-extractor may be placed in a dismal corner since it is safe even if the operator has defective sight or is sickly or is resentful. But a knitting machine has so many fine parts and adjustments that neglect or injury, whether caused by inability to see clearly or by carelessness or by enmity, will ultimately ruin the machine and will injure much fabric in the meantime.

Machine. — The machine considerations are of a different nature than the space considerations, except, of course, that interest on the cost of the machine is constant, so that the machine interest cost per pound of fabric is reduced by increase in the production just as the space interest cost is. But increased production generally involves increased wear and tear on the machine, which increases the cost for maintenance, repair and depreciation, whereas space increase does not.

There are three ways to treat the machinery.

1. To hold back production to preserve the machinery.
2. To increase the profits by rapidly wearing out the machinery.
3. To run the machinery at the maximum earning capacity and to put aside enough of the earnings to replace the machinery when it becomes inefficient.

The first way is the old one, exemplified by the remark "This machine has been in constant use for thirty years and is just as good as new."

The second way is typical of American knitting practice. It requires ultimate increase of capital for new machinery or the use of worn-out machinery at a loss, either of which courses increases the mill's burden and so leads to dissolution.

The third course is apparently the right one. It enables the mill to make a good profit and to keep its equipment modern, so that it has the advantage over new competition of an established business and no disadvantages; whereas under the other methods, while the old mill has the advantage of establishment, it is handicapped by antiquated machinery or by extra interest charges.

It will be considered then that the machine is a means to an end and that it should be used up judiciously, provided that out of its extra earnings enough is saved to replace it with a more modern one and that it is so replaced.

Yarn. — The next consideration is the yarn. It may be cut or torn, and turned into waste, or it may be knit with imperfections which reduce the value of the fabric. This reduction in value should be charged to the cost of manufacture, just as is charged the shrinkage in value from yarn to waste. With some knitting machinery there is a choice whether to use thread stop motions, and frequently there is a question between rewinding and not. But for most rib knitting, thread stop motions are necessary, and since the pros and cons of rewinding are quite well understood, it is considered that stop motions are used and that the yarn is to be knit as supplied, either on cones or bobbins as the case may be. Summarized in regard to the yarn the main considerations are to keep down the waste and to keep up the quality of the fabric.

Operator. — The operator is the most important factor and the most difficult one to control. Not only is his labor a cost item, but he influences almost every other cost, e.g., fixed cost by affecting the rate of production, machinery cost by the care given the machine, and yarn cost both by the attention to the operation of the machine and by the result of the adjustment of the machine. Of course, the cost for operation is reduced by increase in the production per operator.

The question how to get the best results from the operator is too voluminous for extensive treatment here, but a few important considerations may be mentioned. The operator is better led than driven. Preferably, he should be led by inducements to drive himself. There are three good reasons for not driving him. In the first place, he is generally of sufficient intelligence to appreciate reasonable treatment; in the second place, it is difficult to tell that he is not doing his best, and in the third place, he has so much of his employer's property within his control that he is much more independent than help usually is. There is probably no department of the knitting mill which gives better returns for good surroundings and good treatment than the knitting room, and there is only one department which gives better opportunity for resentment — that is the dye room.

From the foregoing it is seen that economy consists in increasing production to that point where the income exceeds to the greatest extent the out-go. It should not be understood from this that a mill running cotton can change to wool at an increased production or at the old production, for the rate of production should always depend on the conditions. But for any given set of conditions the tendency is to increase. Change of yarn or of management or of style of goods may make a sudden decrease, but as soon as conditions become stable, increase should occur; the machinery is built for it, the mill is remodeled for it, survival requires it.

The difference between the total income and out-go is made up of numerous factors. What are they? and can they be changed to advantage?

The production of a rib knitting machine in pounds for 7.5 hours actual time is equal to

$$\frac{\text{dia. in inches} \times \text{feeds} \times \text{r.p.m.} \times \text{cyl. needles per inch (cut)}}{\text{yarn} \times \text{cyl. stitches per foot of yarn}}.$$

Seven and one-half hours time and needles per inch (or cut) are taken in order to eliminate the constants, and to leave in the equation only the variables which determine the production. Evidently, an increase in any of the factors above the line increases the production, but an increase in either of the factors below the line decreases the production, and vice versa. This formula answers the question, what are the mechanical factors which affect production. Whether they can be changed to advantage may be concluded after considering what results will be caused by a change in any one of them. The formula should be kept in mind during the consideration of the subject.

Diameter of Machine

Increase in the diameter without decrease in the speed is the same as increase in the needle velocity; but as it is much easier to get this by increase in the speed, it is generally so done, especially since the diameter of the machine is generally restricted by the width of the fabric. But where there is no such restriction, as sometimes is the case in knitting piece goods, and where the needle velocity is not at its limit, increase of diameter not only increases the production, but provides space for additional feeds with which a still further increase may be made. The effects of increased needle velocity are discussed under Revolutions per Minute.

Revolutions per Minute, or Speed

This factor as a means of increase in production is the one most commonly considered and very generally misunderstood. Anyone who is familiar with knitting and visits knitting mills is struck with the frequency with which he is asked to tell the proprietor how fast he ought to run his machines, often without even seeing the knitting room. This question can be answered reliably only after consideration of the conditions.

The whole subject is analogous to an important feature of the speed question in railroading, i.e., to keep the gain due to accelerated speed more than the increase in losses due to increased accidents and increased trouble resulting therefrom. If a machine doubles its speed, it requires four times the force to stop it in a given distance; or, if the same stopping force is used, the machine will run farther, and will cause extra damage to itself and to the fabric if it is deranged. Fortunately, in this respect, reciprocating needle machinery — to which class most rib machinery belongs — has a considerable friction load which acts as a constant brake so that it stops quicker than purely rotary machinery. The many considerations which enter into this question may be classified as follows:

1. Winding.
2. Yarn, as to material, kind, perfection, size.
3. Stitch, whether tight or loose.
4. Machine, as to equipment, repair and adjustment.
5. Help, as to character and ability.

1. **Winding.** — There is an adage that good winding is half of knitting. That was formulated before thread stop motions were as reliable as they are at present, but the stop motion is much like the policeman — it does not stop all trouble — and the stoppage itself is a loss and a considerable one as the following discussion of feeds shows. Therefore, the winding should be good for increased speed.

2. **The yarn** is dragged into the machine at the rate of about 9 feet per second against the resistance of the cone or bobbin, the air, and the numerous guides through which it passes. A strong, smooth yarn which does not bend too readily will go along without much trouble; but weakness — whether due to character of fibre, size, or spinning — and stickiness — whether due to grease, or to wrapping close around the bearing surfaces — cause trouble, by making the yarn more subject to breakage and by giving it more cause to break. On the other hand, if a strong yarn gets caught, it may break needles before it parts, whereas a weak yarn would have caused less trouble under the same conditions. Woolen yarn is generally more troublesome than cotton yarn. It contains grease which gums the guides, burs which catch and hold it on the bobbin, twits which pull apart readily, soft spots which load up the needles, and lint which collects and binds the drop wires or runs into the machine in wads. Short staple cotton is much the same except that it is stronger and does not contain the grease. Lisle yarn

is the reverse of all this, so it makes one of the best running yarns there is. Floss silk slides readily and has ample strength, but the strands sometimes sliver back, making little lumps in the knitting. Linen and ramie have the strength and sliding properties to feed readily, indeed often to come up too freely, several coils at a time; but they resist bending so much and are so uneven that they are prone to load up the needles. The whole subject is so complex that practical experience is needed to supplement the general principles.

3. **Stitch.** — If the stitch is tight, the speed should be low, for load-ups at high speed are damaging. A loose stitch facilitates high speed.

4. **Machine.** — As a rule, rotary knitting machinery is strong enough to run at a higher rate than that which is warranted by the strength of the yarn and the reliability of the stopping devices; but if it is untrue or inaccurate, if the cams are improperly designed, if the wearing surfaces are of poor material or improperly finished, then the machine itself limits the speed. Consequently, machines out of repair may not be run economically so fast as similar machines in good repair. Also brand-new machines should not be run up to speed until the wearing surfaces are well smoothed by use. Even if the machine itself is all that could be desired, it is impractical to run it fast if it is improperly adjusted, say, if the dial needles interfere with the cylinder needles, etc.

The needles are regarded as a part of the machine, and one of the most important parts. If they are nicked, or worn, or in any way inferior, they limit the speed of the machine.

The stopping devices should be good for increased speed, and should be adjusted accordingly, i.e., the sweep wires, etc., should be placed high, the brakes set to release quickly after the power is thrown off and possibly with increased pressure, etc.

5. **The help** is one of the most important considerations as to whether increased speed is economical, since increased speed calls for alacrity. If the speed of the machine is increased one-third and the speed of the operator not at all, then run downs will be one-third longer and other troubles will be increased. Moreover, with increased speed the damage from smashes is almost sure to increase to an extent, and if this damage is neglected instead of quickly and properly repaired, it increases itself.

Feeds

The equation indicates that an increase in the feeds will increase the production in the same proportion, but this should not be inferred, since the equation does not include waste and lost time factors. The question of the number of feeds generally comes up at the time the machinery is purchased and the manufacturer is usually a good advisor on that subject. He knows quite well how close feeds have been put and what the results have been and it is to his interest to advise, since he wants the machines to give the best all around satisfaction. Then there are such considerations as possible pattern work, making an even number of feeds desirable. But the knitter should know what the truly economical considerations are so that he may use that knowledge in conjunction with what has already been mentioned to adapt the number of feeds to his particular requirements. Some of the off-sets to the gain by increase in the number of feeds are as follows:

1. The lost time due to ends running into the stop motion, or on into the needles is increased in proportion to the number of feeds. Suppose for illustration that one end runs in once an hour at one feed and that a minute is required to restart the machine. If the day is ten hours long, the lost time at that feed is 10 minutes in 600, or 1.67 per cent. Every added feed adds 1.67 per cent to the lost time, since two ends do not break at once as a rule. At the above rate a five-feed machine would lose 8.33 per cent of a day.

2. The damage to needles and to fabric is somewhat increased, since needle protectors are not generally increased at the same rate as the feeds, so that a load-up or a bunch has added opportunity to do damage before the machine is stopped. There are some exceptions to this, such as that in which a needle protector is added after a certain number of feeds so that the protection afterward is greater than it was just before that number was reached.

Needles per Inch, i.e., the Cut

Change in the cut of the machine changes the production in the ratio of the cuts, i.e., a change from 8 to 9 cut changes the production as $9:8 = \frac{9}{8} = 1.12\frac{1}{2}$, or $12\frac{1}{2}$ per cent gain, *provided always that all other conditions are maintained.* Now, the yarn number is determined to an extent by the cut, and the stitch is determined similarly by the yarn number. Moreover, the weight of the fabric is determined by both the number of the yarn and the stitch. So change in the cut introduces complications. Yet the cut is important among the production factors, so the change should be considered on its merits.

Since it is desired to increase production, an increase in the cut is the proposed change. Possibly it is already too fine, and is making more waste than it should for the quantity and quality of the fabric produced; but if this is the case, it will be discovered during the consideration of the plan to make it finer.

Suppose the cut is changed by one needle per inch, say, changed from 8 to 9, but suppose the same number of stitches per foot of yarn is used. As far as the fabric is concerned, this is equivalent to an increase in the diameter of the machine of $\frac{1}{8}$ or $12\frac{1}{2}$ per cent.

Therefore,

(1) the fabric will be $\frac{1}{8}$ wider.
(2) the wales per inch
(3) the courses per inch
(4) the weight per square yard.
} will be unchanged.

Notice that the stitch is kept at the same number of needles per foot of yarn, since it is assumed that the cut is too coarse, so the cut is to be conformed to the stitch instead of vice versa.

Then, as far as the fabric is concerned, the only change necessary is to readjust the machine sizes to the width of the fabric. This is readily done. The main considerations are the adaptability of the cut to the same yarn. When the cut is made finer, the needles are generally decreased in size and, consequently, in strength; moreover, the clearance for the yarn in and between the needles is decreased, so there is the double objection that the yarn is more likely to load up and that the needles are more readily damaged. Consequently, the advisability of change in the cut resolves itself into retention of the gain due to increased production greater than the loss due to increased needle breakage and consequent stoppage. Evidently, the gain due to increased production increases much slower than the loss due to crowding the cut, since this involves not only lost time but damaged needles and damaged fabric. Therefore, the cut should not be made finer, unless it is evident that the original cut is coarse for the yarn. Whether this is so may be determined by the rules and tables given elsewhere, or preferably in the mill itself if several different cuts or different yarn numbers are used.

Suppose the mill runs successfully under the same conditions;

(*a*) 7 cut with 10 yarn, and

(*b*) 10 cut with 16 yarn.

Also suppose the question arises whether the 7-cut machine may advantageously be made finer. From the preceding it is evident that to make it finer without change in other conditions will increase the production, which is advantageous, but will the increased waste and needle breakage counterbalance it?

Now the yarn is proportional to the square of the cut for similar conditions. Conversely, the cut is proportional to the square root of the yarn.

$$\frac{\text{cut}_a}{\text{cut}_b} = \frac{\sqrt{\text{yarn}_a}}{\sqrt{\text{yarn}_b}}$$

$$\text{cut}_a = \text{cut}_b \frac{\sqrt{\text{yarn}_a}}{\sqrt{\text{yarn}_b}}.$$

$$\begin{aligned} \text{cut}_a &= 10 \frac{\sqrt{10}}{\sqrt{16}} \\ &= 10 \sqrt{\frac{10}{16}} \\ &= 10 \sqrt{0.625} \\ &= 10 \times 0.79 \\ &= 7.9, \text{ say } 8. \end{aligned}$$

Therefore, the 7-cut machine may be changed to 8 cut with the result that the new production will be to the old as $8:7 = \frac{8}{7} = 1.143$, or 14.3 per cent gain, and with the expectancy of its running as well as the 10-cut machine.

If the result had come out less than 7, it would have indicated that 7 cut was already too fine, in which case those machines should be watched for waste, and if it were high, then a change to a coarser cut would be advisable, provided that the loss from reduced production would not be more than the gain from reduced waste.

Yarn Number

So far, only the factors of the equation above the line have been considered. It will be noticed that none of them affects the weight per square yard of the fabric. On the contrary, both of the factors below the line do affect the fabric in this regard. Obviously, if the yarn is made heavier, i.e., if the number is reduced, the production in pounds will be increased. The questions which arise regarding such a change are similar to those regarding increase in the cut, except that weight, as well as size, readjustment must be considered. If increased weight per yard is not permissible, then the yarn cannot be changed without a corresponding change in the stitch. Suppose that the fabric may be heavier, there will still be doubt about the advisability of making it so, for if the goods are sold by the dozen and no advance in price is obtained for more weight, it would be foolish to give away some extra weight per dozen just to reduce the knitting cost per pound. But for the sake of argument it may be assumed that heavier weight goods may be marketed at sufficient advance to pay for the extra weight per square yard, as may be the case when the fabric is sold in the roll. Then, of course, whatever reduction may be made in the cost per pound of knitting is gain. So the disadvantages of decreasing the yarn number should be considered, and if they do not outweigh the advantages, the change should be made.

Since the yarn is proportional to the square of the cut, the yarn to be used may be determined just as the cut was determined. For simplicity, the same conditions are assumed as when the cut was considered, except that now the correct yarn number is desired instead of the correct cut. The mill is supposed to be running successfully under similar conditions:

(*a*) 7 cut with 10 yarn, and
(*b*) 10 cut with 16 yarn.

The question is whether coarser yarn may be used on 7 cut and, if so, what number will correspond to 16 yarn on 10 cut.

$$\frac{\text{yarn}_a}{\text{yarn}_b} = \frac{\text{cut}_a^2}{\text{cut}_b^2}.$$

$$\text{yarn}_a = \text{yarn}_b \times \frac{\text{cut}_a^2}{\text{cut}_b^2}$$

$$= 16 \times \frac{7^2}{10^2}$$

$$= 16 \times \frac{49}{100}$$

$$= 7.84, \text{ say } 8.$$

This will change the production as 1/8 : 1/10, or as $\frac{10}{8} = 1.25$, i.e., 25 per cent gain.

It will increase the weight per yard in the same proportion.

The width of the fabric will be changed inversely as the square roots of the yarn numbers, i.e., as

$$\frac{1}{\sqrt{8}} : \frac{1}{\sqrt{10}} = \frac{\sqrt{10}}{\sqrt{8}} = \sqrt{1.25} = 1.12, \text{ or 12 per cent gain.}$$

The courses per inch will be increased to the same extent.

Stitches

The last means to increase the production is to lengthen the stitch, i.e., to decrease the stitches in one foot of yarn. This makes the fabric lighter, since the courses per inch decrease more rapidly than the stitches do.

Suppose that the cut is 7 and that the stitches per foot of yarn are 28. A change to 25 stitches per foot changes the production as $\frac{1}{25} : \frac{1}{28} = \frac{28}{25} = 1.12$, or 12 per cent gain.

The width of the fabric is not changed.

The running of the machine is generally benefited, since a loose stitch favors good running. Of course, if the fabric is made unstable by loosening the stitch, then this means of increasing the production is not permissible.

Conclusion

It should be evident from the foregoing that economical combinations of all of the conditions mentioned are not likely to happen. Indeed it is singular that the combinations which do happen are sufficiently economical to be profitable. But if profit can be made by unscientific methods, then careful investigation ought to pay a good return.

One of the first things to do is to calculate the theoretical production of each machine. The production tables and rules already given afford facilities for such calculations according to whatever conditions have to be met. In general, however, a convenient rule is:

Production, in pounds per day of ten hours, equals

$$\frac{\text{dia. in inches} \times \text{r.p.m.} \times \text{feeds} \times \text{cylinder needles per inch (cut)}}{1.333 \times \text{cotton number of yarn} \times \text{stitches per foot of yarn}}.$$

Now for each machine everything in this equation is generally constant except the yarn number. Substitute in the equation everything except the yarn number, thereby getting a constant which divided by the yarn number at any time that it is convenient gives the production of that machine without the trouble which the whole calculation would involve. For instance, suppose the mill contains among others a machine of the following details, dia. 18 inches; r.p.m., 52; feeds, 12; cut, 8; stitches per foot of yarn, 30. The first four numbers multiplied together give 898,560, which divided by 30×1.333 (= 40) gives 2246.4, the number which divided by the cotton yarn number gives the production for ten hours continuous running. Consequently, if No. 10 yarn is used, the theoretical production is 224.6 lbs. The actual production may be compared with this to obtain the lost time. If the actual production is 180 lbs., the hours lost were $10 \times \frac{44.6}{224.6} = 2$ nearly. It is not right to charge all of this lost time to the operator, because the machine must stop for ends, as a preceding explanation shows. Just what this stoppage is, should be determined by actual count of the stops on one machine, especially if the production drops down. Suppose this twelve-feed machine stops for ends six times an hour. Assume that the operator averages one minute lost time in getting the machine in operation. Then the machine is stopped sixty minutes of the day, or 10 per cent. Since there are 12 ends, the stoppage chargeable to an end is $10 \div 12 = 0.833$ per cent. Therefore, a ten-feed machine will lose 8.33 per cent. Consequently, it would be unfair to expect a man operating machines with 10 feeds to obtain twice the production of one operating an equal number of 5-feed machines. To keep track of the production in this way is to do very much to keep it up; for if the operator knows that his lost time is checked, he will be careful to get to the machines quickly to restart them. If two machines are stopped at a time he will start first the one with the most feeds; and if the yarn comes bad, he will report it quickly rather than accept unjust blame. Moreover, observations of this kind afford a reliable foundation for a merit system of remuneration which will be quickly satisfactory to all concerned, instead of one which will necessitate a probationary period of readjustment with consequent discouragement and dissatisfaction.

Change of Yarn with Corresponding Change of Stitch

One of the commonest considerations is that of the adaptability of the yarn for the cut. This is discussed in the preceding pages for stitch constant, but not for change of stitch, which however is the most frequent combination in which it is met. For instance, a manufacturer buys at bargain price some slightly used machines which are one or two needles per inch coarser than he is using. After he has had them for a time he wonders if they are as much of a bargain as they had seemed as far as production in pounds is concerned. How is he to satisfy himself? This can be done by analysis of the question or by mathematics. The analysis is as follows:

Since the cut is coarse for the yarn, the question is the same as that in which the yarn is fine for the cut, so the latter should be considered, since it is simpler. Suppose that a certain cut with a certain yarn gives the highest knitting economy. Now suppose that finer yarn is used. What is the result as far as production is concerned? Since the yarn is finer, the production (without change of stitch) is changed in inverse proportion to the yarn number. That is, if the change is from No. 10 to No. 20, the production is changed to one-half of what it formerly was, according to the explanation given elsewhere in the book. But fabric made under such conditions would be sleazy, and so probably unsalable. Consequently, the stitches per foot must be increased in order to make satisfactory fabric. Now it has already been shown that it is customary to increase the stitches per foot just as the diameter of the yarn is decreased. But if the stitches per foot are increased, then the length of yarn fed in a given time is proportionately less, consequently, the production is still further decreased. Just how much the two changes affect the production is best shown mathematically.

The production of a rib knitting machine for 7.5 hours is equal to

$$\frac{\text{dia. in inches} \times \text{feeds} \times \text{r.p.m.} \times \text{cut}}{\text{number of yarn} \times \text{cylinder stitches per foot of yarn}}.$$

No quantity above the line is to be changed, but both quantities below the line are to be increased, therefore, the relative production before and after the change is represented by the expression

$$\frac{1}{\text{No.} \times \text{stitches}}.$$

But the stitches are proportional to the $\sqrt{\text{No.}}$ as reference to the rules for regular fabrics shows. Consequently, the production is proportional to

$$\frac{1}{\text{No.} \times \sqrt{\text{No.}}}.$$

But this is a rather inconvenient form for the practical man. It is made more understandable and usable by a reduction to terms of the yarn diameter. The No. is proportional to $\frac{1}{\text{dia.}^2}$ and the $\sqrt{\text{No.}}$ is proportional to $\frac{1}{\text{dia.}}$. Therefore, the production is proportional to dia.^3 Take the illustration already given of the change from No. 10 yarn to No. 20. Their respective diameters and cubes are shown in the following table.

Number	Diameter	Diameter^3
10	15.06	342
20	10.65	121

(The decimal points have been moved to corresponding convenient places in order to avoid confusion in pointing-off, which is permissible, since only relative values are desired, instead of absolute values.) It is evident that the production with No. 10 yarn is nearly three times that with No. 20 yarn. Of course, the supposed change of yarn is greater than any which is apt to occur in practice, but the principle is true regardless of the extent of the change. Accordingly, it is advisable to consider before the use of yarn too fine for the cut, or what is the same thing, cut too coarse for the yarn, for such use very seriously reduces the production. This reduction, by increasing the production cost, increases the final cost, unless compensation is made by changes in other cost factors, such as increase in speed, reduction in waste, etc.

The above discussion makes clear many questions which are generally misunderstood. For illustration, the manufacture of fine flat balbriggan in America is conducted on two different principles: light yarn with a tight stitch, and heavy yarn with a loose stitch. The light-yarn-tight-stitch method gives such a comparatively small production that repeated efforts have been made to account for it by the speed and feeds, but the disparity there is insufficient without the above-mentioned difference due to the yarn and the stitch.

The rate of production of machines using jack sinkers, and, consequently, having a relatively low needle speed, has generally been based on the speed and feeds without considering the important compensation which they have in the increase of production due to the use of heavy yarn, which use is made possible by the jack sinker.

Finally, and generally, the fact that the production in pounds is proportional to the cube of the diameter of the yarn is useful for the selection of machines for special purposes. A machine having loop wheels with fixed blades is especially adapted to knit light yarn, whereas a jack-sinker machine is especially fitted to knit heavy yarn. It is as uneconomical to use a jack-sinker machine for very light yarn as it is to use a loop-wheel machine for very heavy yarn, since the former cannot give a reasonable production and the latter will give unreasonable trouble.

MINIMUM WEIGHT PER SQUARE YARD, YARN-DIAMETER CONSTANT. — DEMONSTRATION

Illustration 1 shows four stitches of plain knit fabric with four wales per inch and one course per inch, as seen with a stitch glass having an opening one inch by one inch.

The following is evident:

There are eight threads crossing the opening.

The average distance between the threads is one yarn diameter. (This is shown by the dotted circles of the same diameter as the yarn and midway between the ends of the loop.)

Now, as the courses per inch decrease, these threads will approach the parallel position, becoming exactly parallel when the courses become zero; but their distance apart will not be changed, since by supposition the yarn diameter is constant. Then a square inch of fabric will be made up of threads an inch long, and the number of these threads will be equal to half the diameters per inch. These relations are true no matter what units be taken, so the weight per square yard will be the weight of as many threads one yard long as half the number of diameters per yard. This is for plain flat fabric. Plain ribbed fabric is the same on the back as it is on the face, so it will have twice as many threads. Therefore, *the minimum weight of ribbed fabric with a given diameter of yarn is the weight of as many yards of that yarn as there are diameters per yard.*

Or,

$$\left.\begin{array}{c}\text{Minimum weight}\\ \text{per square yard}\\ \text{of plain rib fabric}\end{array}\right\} = \begin{array}{c}\text{Weight of one}\\ \text{yard of yarn}\end{array} \times \frac{36}{\text{dia. of yarn, in inches}}.$$

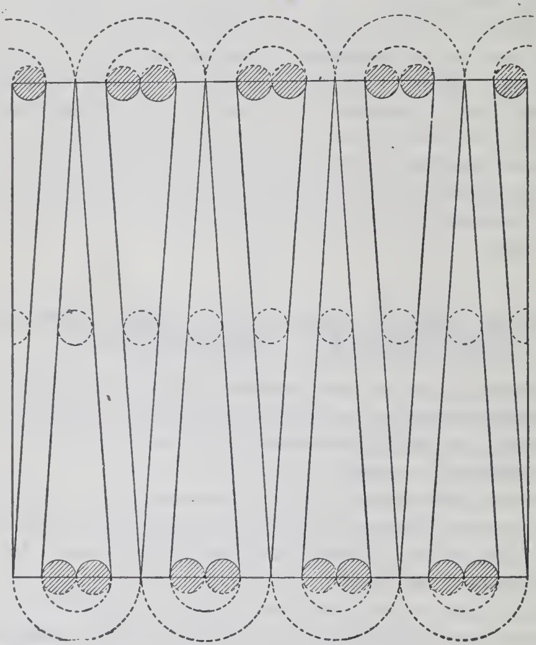


Illustration 1.

Very loose stitches, flat fabric.

What is the minimum weight in pounds per square yard of plain rib fabric made of No. 23 yarn?

$$\frac{1}{23 \times 840} \times \frac{36}{.010} = .1862, \text{ answer.}$$

Brief Chronological List of Important Knitting Inventions

Invention	Date	Inventor	Residence	Authority
Original knitting machine	1589	Wm. Lee	Calverton, Eng.	General.
Rib machine	1758	Jedidah Strutt and Wm. Woollatt	Derby, Eng.	Abridgments Br. Pt's.
Open work	1764	Thos. and John Morris, John and Wm. Betts, also Fernando Shaw	England	Abridgments Br. Pt's Quilter and Chamberlain.
Knit plush	1767	Henry Hardy, Thos. Davies, Andrew Dorilla	England	Abridgments Br. Pt's
Power knitting machine	1769	Samuel Wise	England	Abridgments Br. Pts.
Warp machine	1775	Disputed		Various.
Fleece fabric	1786	Geo. Holland	London, Eng.	Quilter and Chamberlain.
Thread carriers	1789	Rose	Nottingham, Eng.	Quilter and Chamberlain.
Circular knitting machine	1798	Decroix	France	Pierer's Lexicon.
Circular loop-wheel machine	1808	Leroy	Paris	G. Willkomm.
Movable bladed bur	1841	Jacquin	Troyes, France	Franz Reh.
Movable bladed bur with blades moving parallel to needles	1847	Fouquet	Troyes, France	Franz Reh.
Automatic or latch needle	1847	Matthew Townsend	Leicester, Eng.	Quilter and Chamberlain.
Parallel needle upright knitting machine	1849	Moses Mellor	Leicester, Eng.	Felkin.
Circular latch-needle knitting machine	1853	Thompson	Leicester, Eng.	Quilter and Chamberlain.
Large jack-sinker bur	1856	Nopper & Fouquet	Germany	G. Willkomm.
Lamb knitting machine	1863	I. W. Lamb	United States	Quilter and Chamberlain.

THEORY OF KNIT FABRICS

The primary object of this book is to supply useful information for practical knitters. There were two courses open for the accomplishment of that end. One was to collect, edit and print tables and rules from whatever source available. The other course was to endeavor to find the fundamental laws of knitting, to derive comprehensive tables from them, and to put the laws in such simple form that the practical knitter would have available, reliable foundation knowledge of his occupation, which would not only increase his usefulness but would enable him to derive rules and tables which would be generally useful, instead of being restricted to the practice of a single mill as is most of the present information. The latter course was selected, so the task involved not only the computation of original tables and the writing of what was supposed to be desirable explanatory matter, but the more difficult task of the discovery and the proof of the fundamental laws of a big industry in which so few were known that the industry was considered practically lawless. Only the simplest of this research work is thus far included in the book since there is insufficient demand for the remainder to warrant its publication. This limited demand for theoretical matter is not the fault of the individual knitter, but of the industry as a whole. Even at the present time a good knitting education is attained only by practical application so continuous that general education must be curtailed. One of the causes of this is the lack of technical knowledge of the very kind which this book is designed to supply; which lack, in turn, is due to the absence of exact experimental knowledge. Knitting, especially in America, is probably unique as an immense industry without technical literature, without experiment stations, without standards, and possibly not without schools, but certainly without scholars, for the schools have little to teach except that which can be obtained almost as well in practice. They should have what cannot be obtained in practice, that is, the foundation principles. Engineering in all of its branches, astronomy, agriculture, medicine — practically all important divisions of human endeavor — are pushed along by investigations, by schools, by colleges, by associations, and even by the government. But the knitting industry, instead of having all this assistance, seems to lack even the realization of needing it.

In view of the above-mentioned attitude of knitters regarding the slight value of theory, it was concluded not to devote any space to it, but this seemed unfair to the few whose attitude is just the reverse, and more than that it seemed unwise, since it would leave ground for the supposition that the theory is not founded in fact, whereas it is really the expression of demonstrated facts. So it was decided to outline the theory. However, the explanation is made as brief as possible, and in order to secure brevity no attempt is made to popularize the language for those who are not used to elementary experimental science.

The laws are the result of measurements of some 200 samples of rib fabric made in the search for the laws out of single-mule-spun carded cotton yarn, which measurements were interpreted in the light of extensive experience with flat knit fabrics and memorandums of that experience. It is not supposed that all of the laws are final. Indeed those under Case 2 are only partially determined, owing to the lack of sufficient experimental data to warrant definite determination; and it is likely that further investigation will show minor variations in some of those already accepted as practically final. However, no law has been used which did not appear to be as reliable in practice as the average law used as a basis of calculation in every-day affairs. It would be highly desirable to give the percentage of error in these laws. So would it be desirable, and even more so, to give the constants for use with wool, worsted, two-thread work, etc., but this data cannot be derived readily within reasonable time from private experiments. A fair idea of the variation to be expected may be obtained from the tabulation of the dimensions of regular fabrics. Let any one interested compare the dimensions given, with those of a few pieces of fabric which meet the conditions of yarn and stitch. The proportional variation of the actual dimensions from the theoretical, will be a good criterion for the variation.

It should be remembered that take-up pull, hygroscopic conditions, error in the yarn number or diameter, or in the stitches, all enter into the final error. Indeed, one cause of the lack of scientific investigation has undoubtedly been aversion to undertake scientific work with such unsatisfactory measures as are available in knitting, where no dimension, either of weight, diameter or length, is readily obtainable with even fair accuracy.

The following explanation of the terms used is made to avoid cumbering the formulas with details which may just as well be understood once for all.

Stitches are the number of cylinder needles per foot of yarn.

Wales are the number of wales — or ribs — per inch on one side of the fabric.

Courses are the number of courses per inch.

Weight is the weight in pounds of a square yard of fabric.

Diameter is the sensible diameter of the yarn in inches — not the diameter obtained from the specific gravity.

Number is the cotton number of the yarn.

The theory is developed for normal plain rib fabrics, i.e., fabrics in which each and every loop in a course is tangent to the adjacent loops in the same course, but is not tangent to loops of adjoining courses; or in popular language, fabrics which are neither sleazy nor boardy and have properly formed loops.

It is evident that the equations apply also to plain flat knitting, and probably to other kinds of knitting. The only difference is in the constants.

Case 1. — Stitches constant and yarn number variable.. Chart 1.

$$\left.\begin{array}{lll} \text{wales} \times \text{courses} & = \text{a constant} & (1) \\ \text{width} & = \text{dia.} \times \text{a constant} & (2) \\ \text{courses} & = \text{dia.} \times \text{a constant} & (3) \end{array}\right\} \text{from experiment.}$$

All these are straight-line curves. No. 1 is parallel to the axis of diameters. The others pass through the origin, but do not extend to infinity, since the stitch tightens to the breaking point within finite limits.

$$(1) \div (3) \qquad \text{wales} = \frac{\text{a constant}}{\text{dia.}} \quad \ldots\ldots\ldots \quad (4)$$

This curve is of hyperbolic form. For dia. = 0, wales = ∞, and for dia. = ∞, wales = 0, theoretically only, since this is restricted for large diameters just as are Nos. 2 and 3.

The weight per square yard is obtained by combining these equations with the weight per square yard formula which is fully explained elsewhere in the book. No explanation is required here, except that this formula is not dependent on theory but on facts, hence it may properly be used for demonstration. This formula is

$$\text{weight} = \frac{\text{wales} \times \text{courses}}{1.944 \text{ number} \times \text{stitches}}.$$

Relations of Rib-fabric Dimensions for Stitches per Foot of Yarn Constant (30.8) and Size of Yarn Variable.

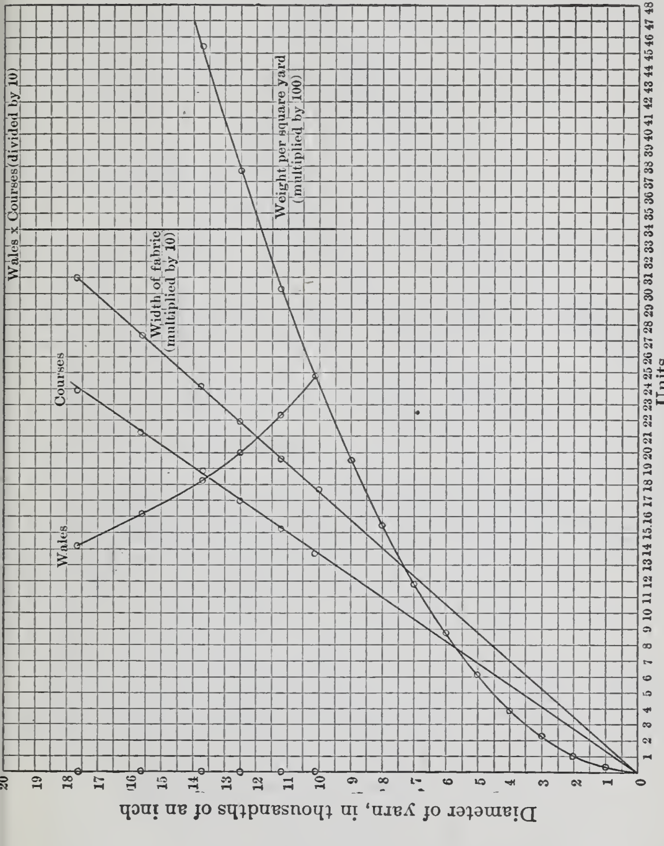


Chart 1. Case 1.

Select the yarn diameter on the left, follow its horizontal line to the right to the curve, and then follow the vertical line to the scale at the bottom.

For instance, for yarn 0.010 inches in diameter:

wales × courses = 34 × 10		= 340.000
courses	=	13.700
wales	=	25.000
width of flattened tube from 88 needles	=	1.760
weight per square yard = 24.2 ÷ 100	=	0.242

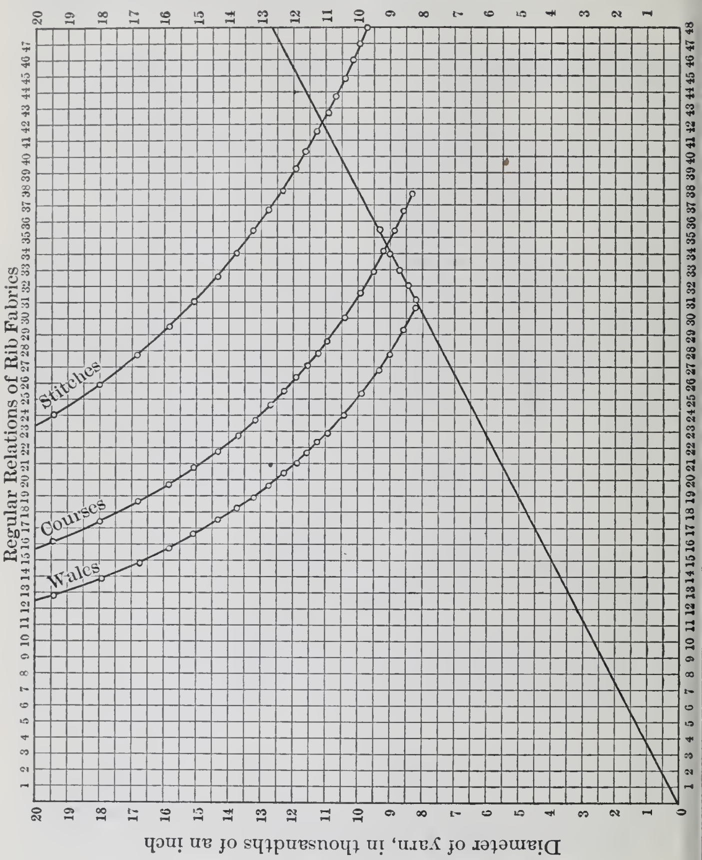


Chart 2. Case 3.

The diagonal is the curve of the weight per square yard multiplied by 100.

Select the yarn diameter on the left, follow its horizontal line to the right to the curve, and then follow the vertical line to the scale at the bottom.

For instance, for yarn .010 inches in diameter:

wales	=		25.00
courses	=		31.30
stitches per foot	=		46.70
weight per sq. yd.	=	38 ÷ 100	0.38

But from No. 1 for stitches constant,

$$\text{wales} \times \text{courses} = \text{a constant.}$$

Therefore,

$$\text{weight} \times \text{number} = \text{a constant.} \quad \ldots\ldots \quad (6)$$

But from the definition of yarn number,

$$\text{number} = \frac{\text{a constant}}{\text{dia}^2.}.$$

Substituting this value for number in (6)

$$\text{weight} = \text{dia.}^2 \times \text{a constant.} \quad \ldots\ldots \quad (7)$$

Therefore, the weight curve is a parabola with its vertex at zero diameter.

Case 2. — Diameter constant and stitches variable. No chart, since such determinations as were made can be shown readily without.

Wales = a constant except for slight *increase* with increase of stitches.

Width = a constant except for slight *decrease* with increase of stitches.

Courses are proportional to stitches, but not directly so.

Weight is proportional to stitches, but not directly so.

The forms of the course and weight curves were not definitely determined. The minimum weight = wt. of 1 yard of yarn $\times \frac{36}{\text{dia.}}$, as is explained in the demonstration given elsewhere of " minimum weight per square yard."

Case 3. — Loop proportional to diameter of yarn. Chart 2. This is the general case. Fabrics under it are called regular fabrics in this book, because the rules are worked out for it quite completely. For the principles see Elements of Knitting in this book, also an article in the " Textile Manufacturers Journal," March 9, 1912, entitled Science in Knitting. No special experimental work was done in this case, since the theory was regarded as sufficiently substantiated without it.

$$\text{wales} \times \text{dia.} = \text{a constant.} \quad \ldots\ldots \quad (8)$$

$$\text{courses} \times \text{dia.} = \text{a constant.} \quad \ldots\ldots \quad (9)$$

$$\text{stitches} \times \text{dia.} = \text{a constant.} \quad \ldots\ldots \quad (10)$$

These curves are all of hyperbolic form, so for dia. = 0, all = ∞. Dia. = ∞, all = 0.

The weight formula

$$\text{weight} \times 1.944 \times \text{number} \times \text{stitches} = \text{wales} \times \text{courses},$$

with the above values and dia. instead of number substituted, becomes

$$\text{weight} \times \frac{\text{const.}}{\text{dia.}^2} \times \frac{\text{const.}}{\text{dia.}} = \frac{1}{1.944} \times \frac{\text{const.}}{\text{dia.}} \times \frac{\text{const.}}{\text{dia.}},$$

from which,

$$\text{weight} = \text{dia.} \times \text{a constant.} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Consequently, the weight curve is a straight line passing through 0 and ∞.

$$(8) \times (9) \quad \text{wales} \times \text{courses} \times \text{dia.}^2 = \text{a constant.} \quad . \quad (12)$$

$$(10) \times (10) \quad \text{stitches}^2 \times \text{dia.}^2 = \text{a constant.} \quad . \quad (13)$$

$$(12) \div (13) \quad \frac{\text{wales} \times \text{courses}}{\text{stitches}^2} = \text{constant.} \quad . \quad (14)$$

THEORY OF KNIT FABRICS — GENERAL CONSIDERATIONS

Although the theory itself is rather technical for knitters as a rule, still the general considerations are not, and they should be read in order to obtain a better understanding of the results worked out by the theory.

In the practical application of the rules and formulas the investigator should consider three important questions: (1) possibility of a misunderstanding of a principle; (2) possible errors due to mistakes in interpreting the experiments; (3) differences of opinion where opinion has to be used. In regard to No. 1, it is believed that no principle has been mistaken. As to No. 2, further investigation may show, for instance, that for stitches constant, the weight per square yard is not exactly inversely proportional to the yarn number. But even if it does so show, the simplicity of this rule and its practical accuracy will undoubtedly keep it in use. However, this should not stand in the way of a more accurate rule if one is obtainable. Regarding No. 3, differences of opinion are bound to occur, for there is no accounting for tastes. But they can be reduced by an explanation of the considerations on which the opinions are based. Consequently, the following explanations are made:

The yarn rules $\left(\text{yarn} = \frac{\text{cut}^2}{6}\right.$ for rib machines, and yarn $= \left.\frac{\text{gauge}^2}{40}\right)$ are not supposed to be restrictive any more than to say a man walks three miles an hour is to mean that he can neither loiter nor run. Everybody knows to the contrary, but to enable mutual understanding it is desirable to have an agreed average standard. The same holds true for the selection of wales to courses as 1 is to 1.25, and for the selection of the speed standards. Probably before long the limits of yarn, speed, and ratio of wales to courses will be determined, and tables will be calculated for short intervals between these, so that the fabric dimensions and related values can be found for practically all conditions. But it would be a waste of time to base such elaborate calculations on such disproportionately scant observations.

It is likely that the stitches per foot used will be found to make rather tight fabric for good running conditions on some machines. This is to be expected, since the theory is developed from consideration of the fabric rather than of the machine. Consequently, if some machine of some particular cut is unsymmetrically designed — and all machines made in a series of cuts are so, since it is impractical to make them otherwise — the formulas should not be considered erroneous for not conforming to that particular machine. Indeed, one of the big advantages of the principles of knitting is the impetus which will be given to systematic knitting machine design. For instance, the design of loop-wheel knitting machinery has been lamentably faulty on the finer gauges, owing partially to the fact that there was not enough call for such gauges to warrant the manufacturer in going to more trouble than to put more needles in the cylinder and more blades in the burs. Consequently, the burs were inordinately big and the needles ridiculously long for the work which they had to do. Such machines will not knit according to the rule on fine gauges, which is not the fault of the rule, but of the machine, for generally what a machine does on one gauge, it should do on another.

This deficiency of machines on the extreme gauges (coarse and fine) is generally true of all types. In some cases it is apparently unavoidable, but in many cases it could be partially remedied, at least, by designing the machine in conformity with the work which it has to do.

One of the most important requisites for the practical application of the principles is the accurate determination of the yarn diameter. Evidently much work must be done in this line on every different kind of material with different twists and different methods of spinning, etc. The diameter here used, namely $\frac{1}{21\sqrt{\text{No.}}}$ seems to be somewhat greater than it should be, as the fabric width given by it for flat-work circular machines indicates, namely 1.26, which is considerably higher than the 1.1 generally allowed. However, it has been considered best to give the formulas just as they work out, and not to shade them in the least, so that the user may learn just how much dependence he may put in them, and may make his own shading once for all. Even when excessive shading is required, the formulas are useful as a proportional guide, which is better than no guide at all.

The Strength of Knit Fabrics

Two factors are considered in the strength question; namely, the number of threads which sustain the stress, and the strength per thread.

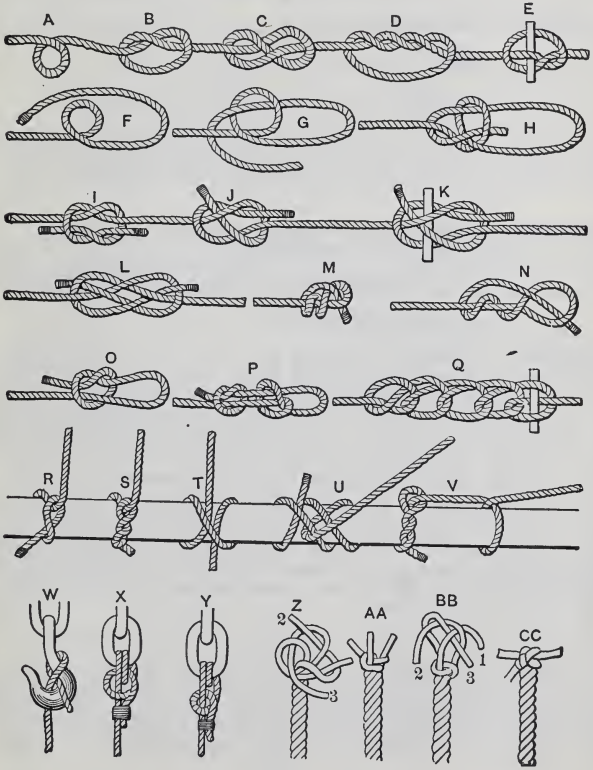
The number of threads crosswise of the fabric is evidently the number of courses per inch, and the number of threads lengthwise of the fabric is the number of wales per inch multiplied by two or by four according to whether the fabric is flat or ribbed.

The strength per thread is based on the Draper Tables of Breaking Weight of American Yarn. The values used are the New Breaking Weight of Soft Twist Yarn, according to which the tensile strength per square inch of sensible cross-sectional area of No. 20 is 7671 pounds, based on the diameter equal to $1 \div 21\sqrt{\text{No.}}$, from which it follows that the tensile strength of the yarn is very nearly $6000 \times (\text{diameter})^2$, which value has been used in calculating the formulas, since the strength of yarn is approximately proportional to the square of the diameter, with variation of a greater decrease in strength than in diameter. The use of $6000 \times (\text{diameter})^2$ for the strength of the yarn makes No. 4 weaker by 13 per cent than the actual tests show, and makes No. 30 stronger by 8 per cent; but these variations are probably no more than would be found in different sections of any one yarn.

The following pages are copied by permission from Kent's "Mechanical Engineers' Pocket Book."

Varieties of Knots. — A great number of knots have been devised of which a few only are illustrated, but those selected are the most frequently used. In the cut, Fig. 81, they are shown open, or before being drawn taut, in order to show the position of the parts. The names usually given to them are:

A. Bight of a rope.
B. Simple or Overhand knot.
C. Figure 8 knot.
D. Double knot.
E. Boat knot.
F. Bowline, first step.
G. Bowline, second step.
H. Bowline completed.
I. Square or reef knot.
J. Sheet bend or weaver's knot.
K. Sheet bend with a toggle.
L. Carrick bend.
M. Stevedore knot completed.
N. Stevedore knot commenced.
O. Slip knot.
P. Flemish loop.
Q. Chain knot with toggle.
R. Half-hitch.
S. Timber-hitch.
T. Clove-hitch.
U. Rolling-hitch.
V. Timber-hitch and half-hitch.
W. Blackwall-hitch.
X. Fisherman's bend.
Y. Round turn and half-hitch
Z. Wall knot commenced.
AA. Wall knot completed.
BB. Wall knot crown commenced.
CC. Wall knot crown completed.



KNOTS.

RATIO AND PROPORTION.

Ratio is the relation of one number to another, as obtained by dividing the first number by the second. Synonymous with quotient.

Ratio of 2 to 4, or $2 : 4 = 2/4 = 1/2$.
Ratio of 4 to 2, or $4 : 2 = 2$.

Proportion is the equality of two ratios. Ratio of 2 to 4 equals ratio of 3 to 6, $2/4 = 3/6$; expressed thus, $2 : 4 :: 3 : 6$: read, 2 is to 4 as 3 is to 6.

The first and fourth terms are called the extremes or outer terms, the second and third the means or inner terms.

The product of the means equals the product of the extremes:

$$2 : 4 :: 3 : 6; \quad 2 \times 6 = 12; \quad 3 \times 4 = 12.$$

Hence, given the first three terms to find the fourth, multiply the second and third terms together and divide by the first.

$$2 : 4 :: 3 : \text{what number?} \quad \text{Ans. } \frac{4 \times 3}{2} = 6.$$

Algebraic expression of proportion. — $a : b :: c : d$; $\frac{a}{b} = \frac{c}{d}$; $ad = bc$; from which $a = \frac{bc}{d}$; $d = \frac{bc}{a}$; $b = \frac{ad}{c}$; $c = \frac{ad}{b}$.

From the above equations may also be derived the following:

$b : a :: d : c$ $\quad$ $a + b : a :: c + d : c$ $\quad$ $a + b : a - b :: c + d : c - d$
$a : c :: b : d$ $\quad$ $a + b : b :: c + d : d$ $\quad$ $a^n : b^n :: c^n : d^n$
$a : b = c : d$ $\quad$ $a - b : b :: c - d : d$ $\quad$ $\sqrt[n]{a} : \sqrt[n]{b} :: \sqrt[n]{c} \; \sqrt[n]{d}$
$a - b : a :: c - d : c$

Mean proportional between two given numbers, 1st and 2d, is such a number that the ratio which the first bears to it equals the ratio which it bears to the second. Thus, $2 : 4 :: 4 : 8$; 4 is a mean proportional between 2 and 8. To find the mean proportional between two numbers, extract the square root of their product.

$$\text{Mean proportional of 2 and 8} = \sqrt{2 \times 8} = 4.$$

Single Rule of Three; or, finding the fourth term of a proportion when three terms are given. — Rule, as above, when the terms are stated in their proper order, multiply the second by the third and divide by the first. The difficulty is to state the terms in their proper order. The term which is of the same kind as the required or fourth term is made the third; the first and second must be like each other in kind and denomination. To determine which is to be made second and which first requires a little reasoning. If an inspection of the problem shows that the answer should be greater than the third term, then the greater of the other two given terms should be made the second term — otherwise the first. Thus, 3 men remove 54 cubic feet of rock in a day; how many men will remove in the same time 10 cubic yards? The answer is to be men — make men third term; the answer is to be more than three men, therefore make the greater quantity, 10 cubic yards, the second term; but as it is not the same denomination as the other term it must be reduced, = 270 cubic feet. The proportion is then stated:

$$54 : 270 :: 3 : x \text{ (the required number)}; \; x = \frac{3 \times 270}{54} = 15 \text{ men.}$$

The problem is more complicated if we increase the number of given terms. Thus, in the above question, substitute for the words "in the same time" the words "in 3 days." First solve it as above, as if the work were to be done in the same time; then make another proportion, stating it thus: If 15 men do it in the same time, it will take fewer men to do it in 3 days; make 1 day the second term and 3 days the first term. 3 : 1 :: 15 men : 5 men.

Decimal Equivalents of Fractions of One Inch.

1–64	.015625	17–64	.265625	33–64	.515625	49–64	.765625
1–32	.03125	9–32	.28125	17–32	.53125	25–32	.78125
3–64	.046875	19–64	.296875	35–64	.546875	51–64	.796875
1-16	.0625	**5-16**	.3125	**9-16**	.5625	**13-16**	.8125
5–64	.078125	21–64	.328125	37–64	.578125	53–64	.828125
3–32	.09375	11–32	.34375	19–32	.59375	27–32	.84375
7–64	.109375	23–64	.359375	39–64	.609375	55–64	.859375
1-8	.125	**3-8**	.375	**5-8**	.625	**7-8**	.875
9–64	.140625	25–64	.390625	41–64	.640625	57–64	.890625
5–32	.15625	13–32	.40625	21–32	.65625	29–32	.90625
11–64	.171875	27–64	.421875	43–64	.671875	59–64	.921875
3-16	.1875	**7-16**	.4375	**11-16**	.6875	**15-16**	.9375
13–64	.203125	29–64	.453125	45–64	.703125	61–64	.953125
7–32	.21875	15–32	.46875	23–32	.71875	31–32	.96875
15–64	.234375	31–64	.484375	47–64	.734375	63–64	.984375
1-4	.25	**1-2**	.50	**3-4**	.75	**1**	**1.**

Long Measure. — Measures of Length.

12 inches = 1 foot.
3 feet = 1 yard.
1760 yards, or 5280 feet = 1 mile.

Additional measures of length in occasional use: 1000 mils = 1 inch; 4 inches = 1 hand; 9 inches = 1 span; $2^1/_2$ feet = 1 military pace; 2 yards = 1 fathom; $5^1/_2$ yards, or $16^1/_2$ feet = 1 rod (formerly also called pole or perch).

Measures of Weight. — Avoirdupois, or Commercial Weight.

16 drachms, or 437.5 grains = 1 ounce, oz.
16 ounces, or 7000 grains = 1 pound, lb.
28 pounds = 1 quarter, qr.
4 quarters = 1 hundredweight, cwt. = 112 lbs.
20 hundred weight = 1 ton of 2240 lbs., gross or long ton.
2000 pounds = 1 net, or short ton.
2204.6 pounds = 1 metric ton.
1 stone = 14 pounds; 1 quintal = 100 pounds.

The drachm, quarter, hundredweight, stone, and quintal are now seldom used in the United States.

Measures of Work, Power, and Duty.

Work. — The sustained exertion of pressure through space.

Unit of work. — One foot-pound, i.e., a pressure of one pound exerted through a space of one foot.

Horse-power. — The rate of work. Unit of horse-power = 33,000 ft.-lbs. per minute, or 550 ft.-lbs. per second = 1,980,000 ft.-lbs. per hour.

Heat unit = heat required to raise 1 lb. of water 1° F. (from 39° to 40°).

Horse-power expressed in heat units = $\frac{33000}{778}$ = 42.416 heat units per minute = 0.707 heat unit per second = 2545 heat units per hour.

1 lb. of fuel per H. P. per hour = $\begin{cases}\text{1,980,000 ft.-lbs. per lb. of fuel.} \\ \text{2,545 heat units " " " "}\end{cases}$

1,000,000 ft.-lbs. per lb. of fuel = 1.98 lbs. of fuel per H. P. per hour.

Velocity.—Feet per second = $\frac{5280}{3600} = \frac{22}{15} \times$ miles per hour.

Gross tons per mile = $\frac{1760}{2240} = \frac{11}{14}$ **lbs. per yard (single rail.)**

SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS

No.	Square.	Cube.	Sq. Root.	Cube Root.	No.	Square.	Cube.	Sq. Root.	Cube Root.
0.1	.01	.001	.3162	.4642	3.1	9.61	29.791	1.761	1.458
.15	.0225	.0034	.3873	.5313	.2	10.24	32.768	1.789	1.474
.2	.04	.008	.4472	.5848	.3	10.89	35.937	1.817	1.489
.25	.0625	.0156	.500	.6300	.4	11.56	39.304	1.844	1.504
.3	.09	.027	.5477	.6694	.5	12.25	42.875	1.871	1.518
.35	.1225	.0429	.5916	.7047	.6	12.96	46.656	1.897	1.533
.4	16	.064	.6325	.7368	.7	13.69	50.653	1.924	1.547
.45	.2025	.0911	.6708	.7663	.8	14.44	54.872	1.949	1.560
.5	.25	.125	.7071	.7937	.9	15.21	59.319	1.975	1.574
.55	.3025	.1664	.7416	.8193	**4.**	16.	64.	2.	1.5874
.6	.36	.216	.7746	.8434	.1	16.81	68.921	2.025	1.601
.65	.4225	.2746	.8062	.8662	.2	17.64	74.088	2.049	1.613
.7	.49	.343	.8367	.8879	.3	18.49	79.507	2.074	1.626
.75	.5625	.4219	.8660	.9086	.4	19.36	85.184	2.098	1.639
.8	.64	.512	.8944	.9283	.5	20.25	91.125	2.121	1.651
.85	.7225	.6141	.9219	.9473	.6	21.16	97.336	2.145	1.663
.9	.81	.729	.9487	.9655	.7	22.09	103.823	2.168	1.675
.95	.9025	.8574	.9747	.9830	.8	23.04	110.592	2.191	1.687
1.	1.	1.	1.	1.	.9	24.01	117.649	2.214	1.698
1.05	1.1025	1.158	1.025	1.016	**5.**	25.	125.	2.2361	1.7100
1.1	1.21	1.331	1.049	1.032	.1	26.01	132.651	2.258	1.721
1.15	1.3225	1.521	1.072	1.048	.2	27.04	140.608	2.280	1.732
1.2	1.44	1.728	1.095	1.063	.3	28.09	148.877	2.302	1.744
1.25	1.5625	1.953	1.118	1.077	.4	29.16	157.464	2.324	1.754
1.3	1.69	2.197	1.140	1.091	.5	30.25	166.375	2.345	1.765
1.35	1.8225	2.460	1.162	1.105	.6	31.36	175.616	2.366	1.776
1.4	1.96	2.744	1.183	1.119	.7	32.49	185.193	2.387	1.786
1.45	2.1025	3.049	1.204	1.132	.8	33.64	195.112	2.408	1.797
1.5	2.25	3.375	1.2247	1.1447	.9	34.81	205.379	2.429	1.807
1.55	2.4025	3.724	1.245	1.157	**6.**	36.	216.	2.4495	1.8171
1.6	2.56	4.096	1.265	1.170	.1	37.21	226.981	2.470	1.827
1.65	2.7225	4.492	1.285	1.182	.2	38.44	238.328	2.490	1.837
1.7	2.89	4.913	1.304	1.193	.3	39.69	250.047	2.510	1.847
1.75	3.0625	5.359	1.323	1.205	.4	40.96	262.144	2.530	1.857
1.8	3.24	5.832	1.342	1.216	.5	42.25	274.625	2.550	1.866
1.85	3.4225	6.332	1.360	1.228	.6	43.56	287.496	2.569	1.876
1.9	3.61	6.859	1.378	1.239	.7	44.89	300.763	2.588	1.885
1.95	3.8025	7.415	1.396	1.249	.8	46.24	314.432	2.608	1.895
2.	4.	8.	1.4142	1.2599	.9	47.61	328.509	2.627	1.904
.1	4.41	9.261	1.449	1.281	**7.**	49.	343.	2.6458	1.9129
.2	4.84	10.648	1.483	1.301	.1	50.41	357.911	2.665	1.922
.3	5.29	12.167	1.517	1.320	.2	51.84	373.248	2.683	1.931
.4	5.76	13.824	1.549	1.339	.3	53.29	389.017	2.702	1.940
.5	6.25	15.625	1.581	1.357	.4	54.76	405.224	2.720	1.949
.6	6.76	17.576	1.612	1.375	.5	56.25	421.875	2.739	1.957
.7	7.29	19.683	1.643	1.392	.6	57.76	438.976	2.757	1.966
.8	7.84	21.952	1.673	1.409	.7	59.29	456.533	2.775	1.975
.9	8.41	24.389	1.703	1.426	.8	60.84	474.552	2.793	1.983
3.	9.	27.	1.7321	1.4422	.9	62.41	493.039	2.811	1.992

No.	Square.	Cube.	Sq. Root.	Cube Root.	No.	Square	Cube.	Sq. Root.	Cube Root.
8.	64.	512.	2.8284	2.	45	2025	91125	6.7082	3.5569
.1	65.61	531.441	2.846	2.008	46	2116	97336	6.7823	3.5830
.2	67.24	551.368	2.864	2.017	47	2209	103823	6.8557	3.6088
.3	68.89	571.787	2.881	2.025	48	2304	110592	6.9282	3.6342
.4	70.56	592.704	2.898	2.033	49	2401	117649	7.	3.6593
.5	72.25	614.125	2.915	2.041	50	2500	125000	7.0711	3.6840
.6	73.96	636.056	2.933	2.049	51	2601	132651	7.1414	3.7084
.7	75.69	658.503	2.950	2.057	52	2704	140608	7.2111	3.7325
.8	77.44	681.472	2.966	2.065	53	2809	148877	7.2801	3.7563
.9	79.21	704.969	2.983	2.072	54	2916	157464	7.3485	3.7798
9.	81.	729.	3.	2.0801	55	3025	166375	7.4162	3.8030
.1	82.81	753.571	3.017	2.088	56	3136	175616	7.4833	3.8259
.2	84.64	778.688	3.033	2.095	57	3249	185193	7.5498	3.8485
.3	86.49	804.357	3.050	2.103	58	3364	195112	7.6158	3.8709
.4	88.36	830.584	3.066	2.110	59	3481	205379	7.6811	3.8930
.5	90.25	857.375	3.082	2.118	60	3600	216000	7.7460	3.9149
.6	92.16	884.736	3.098	2.125	61	3721	226981	7.8102	3.9365
.7	94.09	912.673	3.114	2.133	62	3844	238328	7.8740	3.9579
.8	96.04	941.192	3.130	2.140	63	3969	250047	7.9373	3.9791
.9	98.01	970.299	3.146	2.147	64	4096	262144	8.	4.
10	100	1000	3.1623	2.1544	65	4225	274625	8.0623	4.0207
11	121	1331	3.3166	2.2240	66	4356	287496	8.1240	4.0412
12	144	1728	3.4641	2.2894	67	4489	300763	8.1854	4.0615
13	169	2197	3.6056	2.3513	68	4624	314432	8.2462	4.0817
14	196	2744	3.7417	2.4101	69	4761	328509	8.3066	4.1016
15	225	3375	3.8730	2.4662	70	4900	343000	8.3666	4.1213
16	256	4096	4.	2.5198	71	5041	357911	8.4261	4.1408
17	289	4913	4.1231	2.5713	72	5184	373248	8.4853	4.1602
18	324	5832	4.2426	2.6207	73	5329	389017	8.5440	4.1793
19	361	6859	4.3589	2.6684	74	5476	405224	8.6023	4.1983
20	400	8000	4.4721	2.7144	75	5625	421875	8.6603	4.2172
21	441	9261	4.5826	2.7589	76	5776	438976	8.7178	4.2358
22	484	10648	4.6904	2.8020	77	5929	456533	8.7750	4.2543
23	529	12167	4.7958	2.8439	78	6084	474552	8.8318	4.2727
24	576	13824	4.8990	2.8845	79	6241	493039	8.8882	4.2908
25	625	15625	5.	2.9240	80	6400	512000	8.9443	4.3089
26	676	17576	5.0990	2.9625	81	6561	531441	9.	4.3267
27	729	19683	5.1962	3.	82	6724	551368	9.0554	4.3445
28	784	21952	5.2915	3.0366	83	6889	571787	9.1104	4.3621
29	841	24389	5.3852	3.0723	84	7056	592704	9.1652	4.3795
30	900	27000	5.4772	3.1072	85	7225	614125	9.2195	4.3968
31	961	29791	5.5678	3.1414	86	7396	636056	9.2736	4.4140
32	1024	32768	5.6569	3.1748	87	7569	658503	9.3276	4.4310
33	1089	35937	5.7446	3.2075	88	7744	681472	9.3808	4.4480
34	1156	39304	5.8310	3.2396	89	7921	704969	9.4340	4.4647
35	1225	42875	5.9161	3.2711	90	8100	729000	9.4868	4.4814
36	1296	46656	6.	3.3019	91	8281	753571	9.5394	4.4979
37	1369	50653	6.0828	3.3322	92	8464	778688	9.5917	4.5144
38	1444	54872	6.1644	3.3620	93	8649	804357	9.6437	4.5307
39	1521	59319	6.2450	3.3912	94	8836	830584	9.6954	4.5468
40	1600	64000	6.3246	3.4200	95	9025	857375	9.7468	4.5629
41	1681	68921	6.4031	3.4482	96	9216	884736	9.7980	4.5789
42	1764	74088	6.4807	3.4760	97	9409	912673	9.8489	4.5947
43	1849	79507	6.5574	3.5034	98	9604	941192	9.8995	4.6104
44	1936	85184	6.6332	3.5303	99	9801	970299	9.9499	4.6261

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diam.	Circum.	Area.
1/64	.04909	.00019
1/32	.09818	.00077
3/64	.14726	.00173
1/16	.19635	.00307
3/32	.29452	.00690
1/8	.39270	.01227
5/32	.49087	.01917
3/16	.58905	.02761
7/32	.68722	.03758
1/4	.78540	.04909
9/32	.88357	.06213
5/16	.98175	.07670
11/32	1.0799	.09281
3/8	1.1781	.11045
13/32	1.2763	.12962
7/16	1.3744	.15033
15/32	1.4726	.17257
1/2	1.5708	.19635
17/32	1.6690	.22166
9/16	1.7671	.24850
19/32	1.8653	.27688
5/8	1.9635	.30680
21/32	2.0617	.33824
11/16	2.1598	.37122
23/32	2.2580	.40574
3/4	2.3562	.44179
25/32	2.4544	.47937
13/16	2.5525	.51849
27/32	2.6507	.55914
7/8	2.7489	.60132
29/32	2.8471	.64504
15/16	2.9452	.69029
31/32	3.0434	.73708
1.	3.1416	.7854
1/16	3.3379	.8866
1/8	3.5343	.9940
3/16	3.7306	1.1075
1/4	3.9270	1.2272
5/16	4.1233	1.3530
3/8	4.3197	1.4849
7/16	4.5160	1.6230
1/2	4.7124	1.7671
9/16	4.9087	1.9175
5/8	5.1051	2.0739
11/16	5.3014	2.2365
3/4	5.4978	2.4053
13/16	5.6941	2.5802
7/8	5.8905	2.7612
15/16	6.0868	2.9483
2.	6.2832	3.1416
1/16	6.4795	3.3410
1/8	6.6759	3.5466
3/16	6.8722	3.7583
1/4	7.0686	3.9761
5/16	7.2649	4.2000

Diam.	Circum.	Area.
2 3/8	7.4613	4.4301
7/16	7.6576	4.6664
1/2	7.8540	4.9087
9/16	8.0503	5.1572
5/8	8.2467	5.4119
11/16	8.4430	5.6727
3/4	8.6394	5.9396
13/16	8.8357	6.2126
7/8	9.0321	6.4918
15/16	9.2284	6.7771
3.	9.4248	7.0686
1/16	9.6211	7.3662
1/8	9.8175	7.6699
3/16	10.014	7.9798
1/4	10.210	8.2958
5/16	10.407	8.6179
3/8	10.603	8.9462
7/16	10.799	9.2806
1/2	10.996	9.6211
9/16	11.192	9.9678
5/8	11.388	10.321
11/16	11.585	10.680
3/4	11.781	11.045
13/16	11.977	11.416
7/8	12.174	11.793
15/16	12.370	12.177
4.	12.566	12.566
1/16	12.763	12.962
1/8	12.959	13.364
3/16	13.155	13.772
1/4	13.352	14.186
5/16	13.548	14.607
3/8	13.744	15.033
7/16	13.941	15.466
1/2	14.137	15.904
9/16	14.334	16.349
5/8	14.530	16.800
11/16	14.726	17.257
3/4	14.923	17.721
13/16	15.119	18.190
7/8	15.315	18.665
15/16	15.512	19.147
5.	15.708	19.635
1/16	15.904	20.129
1/8	16.101	20.629
3/16	16.297	21.135
1/4	16.493	21.648
5/16	16.690	22.166
3/8	16.886	22.691
7/16	17.082	23.221
1/2	17.279	23.758
9/16	17.475	24.301
5/8	17.671	24.850
11/16	17.868	25.406
3/4	18.064	25.967
13/16	18.261	26.535
7/8	18.457	27.109
15/16	18.653	27.688
6.	18.850	28.274

Diam.	Circum.	Area.
6 1/8	19.242	29.465
1/4	19.635	30.680
3/8	20.028	31.919
1/2	20.420	33.183
5/8	20.813	34.472
3/4	21.206	35.785
7/8	21.598	37.122
7.	21.991	38.485
1/8	22.384	39.871
1/4	22.776	41.282
3/8	23.169	42.718
1/2	23.562	44.179
5/8	23.955	45.664
3/4	24.347	47.173
7/8	24.740	48.707
8.	25.133	50.265
1/8	25.525	51.849
1/4	25.918	53.456
3/8	26.311	55.088
1/2	26.704	56.745
5/8	27.096	58.426
3/4	27.489	60.132
7/8	27.882	61.862
9.	28.274	63.617
1/8	28.667	65.397
1/4	29.060	67.201
3/8	29.452	69.029
1/2	29.845	70.882
5/8	30.238	72.760
3/4	30.631	74.662
7/8	31.023	76.589
10.	31.416	78.540
1/8	31.809	80.516
1/4	32.201	82.516
3/8	32.594	84.541
1/2	32.987	86.590
5/8	33.379	88.664
3/4	33.772	90.763
7/8	34.165	92.886
11.	34.558	95.033
1/8	34.950	97.205
1/4	35.343	99.402
3/8	35.736	101.62
1/2	36.128	103.87
5/8	36.521	106.14
3/4	36.914	108.43
7/8	37.306	110.75
12.	37.699	113.10
1/8	38.092	115.47
1/4	38.485	117.86
3/8	38.877	120.28
1/2	39.270	122.72
5/8	39.663	125.19
3/4	40.055	127.68
7/8	40.448	130.19
13.	40.841	132.73
1/8	41.233	135 30
1/4	41.626	137.89
3/8	42.019	140.50
1/2	42.412	143.14

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
13 5/8	42.804	145.80	**21** 7/8	68.722	375.83	**30** 1/8	94.640	712.76
3/4	43.197	148.49	**22.**	69.115	380.13	1/4	95.033	718.69
7/8	43.590	151.20	1/8	69.508	384.46	3/8	95.426	724.64
14.	43.982	153.94	1/4	69.900	388.82	1/2	95.819	730.62
1/8	44.375	156.70	3/8	70.293	393.20	5/8	96.211	736.62
1/4	44.768	159.48	1/2	70.686	397.61	3/4	96.604	742.64
3/8	45.160	162.30	5/8	71.079	402.04	7/8	96.997	748.69
1/2	45.553	165.13	3/4	71.471	406.49	**31.**	97.389	754.77
5/8	45.946	167.99	7/8	71.864	410.97	1/8	97.782	760.87
3/4	46.338	170.87	**23.**	72.257	415.48	1/4	98.175	766.99
7/8	46.731	173.78	1/8	72.649	420.00	3/8	98.567	773.14
15.	47.124	176.71	1/4	73.042	424.56	1/2	98.960	779.31
1/8	47.517	179.67	3/8	73.435	429.13	5/8	99.353	785.51
1/4	47.909	182.65	1/2	73.827	433.74	3/4	99.746	791 73
3/8	48.302	185.66	5/8	74.220	438.36	7/8	100.138	797.98
1/2	48.695	188.69	3/4	74.613	443.01	**32.**	100.531	804.25
5/8	49.087	191.75	7/8	75.006	447.69	1/8	100.924	810.54
3/4	49.480	194.83	**24.**	75.398	452.39	1/4	101.316	816.86
7/8	49.873	197.93	1/8	75.791	457.11	3/8	101.709	823.21
16.	50.265	201.06	1/4	76.184	461.86	1/2	102.102	829.58
1/8	50.658	204.22	3/8	76.576	466.64	5/8	102.494	835.97
1/4	51.051	207.39	1/2	76.969	471.44	3/4	102.887	842.39
3/8	51.444	210.60	5/8	77.362	476.26	7/8	103.280	848.83
1/2	51.836	213.82	3/4	77.754	481.11	**33.**	103.673	855.30
5/8	52.229	217.08	7/8	78.147	485.98	1/8	104.065	861.79
3/4	52.622	220.35	**25.**	78.540	490.87	1/4	104.458	868.31
7/8	53.014	223.65	1/8	78.933	495.79	3/8	104.851	874.85
17.	53.407	226.98	1/4	79.325	500.74	1/2	105.243	881.41
1/8	53.800	230.33	3/8	79.718	505.71	5/8	105.636	888.00
1/4	54.192	233.71	1/2	80.111	510.71	3/4	106.029	894.62
3/8	54.585	237.10	5/8	80.503	515.72	7/8	106.421	901.26
1/2	54.978	240.53	3/4	80.896	520.77	**34.**	106.814	907.92
5/8	55.371	243.98	7/8	81.289	525.84	1/8	107.207	914.61
3/4	55.763	247.45	**26.**	81.681	530.93	1/4	107.600	921.32
7/8	56.156	250.95	1/8	82.074	536.05	3/8	107.992	928.06
18.	56.549	254.47	1/4	82.467	541.19	1/2	108.385	934.82
1/8	56.941	258.02	3/8	82.860	546.35	5/8	108.778	941.61
1/4	57.334	261.59	1/2	83.252	551.55	3/4	109.170	948.42
3/8	57.727	265.18	5/8	83.645	556.76	7/8	109.563	955.25
1/2	58.119	268.80	3/4	84.038	562.00	**35.**	109.956	962.11
5/8	58.512	272.45	7/8	84.430	567.27	1/8	110.348	969.00
3/4	58.905	276.12	**27.**	84.823	572.56	1/4	110.741	975.91
7/8	59.298	279.81	1/8	85.216	577.87	3/8	111.134	982.84
19.	59.690	283.53	1/4	85.608	583.21	1/2	111.527	989.80
1/8	60.083	287.27	3/8	86.001	588.57	5/8	111.919	996.78
1/4	60.476	291.04	1/2	86.394	593.96	3/4	112.312	1003.8
3/8	60.868	294.83	5/8	86.786	599.37	7/8	112.705	1010.8
1/2	61.261	298.65	3/4	87.179	604.81	**36.**	113.097	1017.9
5/8	61.654	302.49	7/8	87.572	610.27	1/8	113.490	1025.0
3/4	62.046	306.35	**28.**	87.965	615.75	1/4	113.883	1032.1
7/8	62.439	310.24	1/8	88.357	621.26	3/8	114.275	1039.2
20.	62.832	314.16	1/4	88.750	626.80	1/2	114.668	1046.3
1/8	63.225	318.10	3/8	89.143	632.36	5/8	115.061	1053.5
1/4	63.617	322.06	1/2	89.535	637.94	3/4	115.454	1060.7
3/8	64.010	326.05	5/8	89.928	643.55	7/8	115.846	1068.0
1/2	64.403	330.06	3/4	90.321	649.18	**37.**	116.239	1075.2
5/8	64.795	334.10	7/8	90.713	654.84	1/8	116.632	1082.5
3/4	65.188	338.16	**29.**	91.106	660.52	1/4	117.024	1089.8
7/8	65.581	342.25	1/8	91.499	666.23	3/8	117.417	1097.1
21.	65.973	346.36	1/4	91.892	671.96	1/2	117.810	1104.5
1/8	66.366	350.50	3/8	92.284	677.71	5/8	118.202	1111.8
1/4	66.759	354.66	1/2	92.677	683.49	3/4	118.596	1119.2
3/8	67.152	358.84	5/8	93.070	689.30	7/8	118.988	1126.7
1/2	67.544	363.05	3/4	93.462	695.13	**38.**	119.381	1134.1
5/8	67.937	367.28	7/8	93.855	700.98	1/8	119.773	1141.6
3/4	68.330	371.54	**30.**	94.248	706.86	1/4	120.166	1149.1

NATURAL TRIGONOMETRICAL FUNCTIONS.

°	M.	Sine.	Co-Vers.	Cosec.	Tang.	Cotan.	Se-cant.	Ver. Sin.	Cosine.		
0	0	.00000	1.0000	Infinite	.00000	Infinite	1.0000	.00000	1.0000	90	0
	15	.00436	.99564	229.18	.00436	229.18	1.0000	.00001	.99999		45
	30	.00873	.99127	114.59	.00873	114.59	1.0000	.00004	.99996		30
	45	.01309	.98691	76.397	.01309	76.390	1.0001	.00009	.99991		15
1	0	.01745	.98255	57.299	.01745	57.290	1.0001	.00015	.99985	89	0
	15	.02181	.97819	45.840	.02182	45.829	1.0002	.00024	.99976		45
	30	.02618	.97382	38.202	.02618	38.188	1.0003	.00034	.99966		30
	45	.03054	.96946	32.746	.03055	32.730	1.0005	.00047	.99953		15
2	0	.03490	.96510	28.654	.03492	28.636	1.0006	.00061	.99939	88	0
	15	.03926	.96074	25.471	.03929	25.452	1.0008	.00077	.99923		45
	30	.04362	.95638	22.926	.04366	22.904	1.0009	.00095	.99905		30
	45	.04798	.95202	20.843	.04803	20.819	1.0011	.00115	.99885		15
3	0	.05234	.94766	19.107	.05241	19.081	1.0014	.00137	.99863	87	0
	15	.05669	.94331	17.639	.05678	17.611	1.0016	.00161	.99839		45
	30	.06105	.93895	16.380	.06116	16.350	1.0019	.00187	.99813		30
	45	.06540	.93460	15.290	.06554	15.257	1.0021	.00214	.99786		15
4	0	.06976	.93024	14.336	.06993	14.301	1.0024	.00244	.99756	86	0
	15	.07411	.92589	13.494	.07431	13.457	1.0028	.00275	.99725		45
	30	.07846	.92154	12.745	.07870	12.706	1.0031	.00308	.99692		30
	45	.08281	.91719	12.076	.08309	12.035	1.0034	.00343	.99656		15
5	0	.08716	.91284	11.474	.08749	11.430	1.0038	.00381	.99619	85	0
	15	.09150	.90850	10.929	.09189	10.883	1.0042	.00420	.99580		45
	30	.09585	.90415	10.433	.09629	10.385	1.0046	.00460	.99540		30
	45	.10019	.89981	9.9812	.10069	9.9310	1.0051	.00503	.99497		15
6	0	.10453	.89547	9.5668	.10510	9.5144	1.0055	.00548	.99452	84	0
	15	.10887	.89113	9.1855	.10952	9.1309	1.0060	.00594	.99406		45
	30	.11320	.88680	8.8337	.11393	8.7769	1.0065	.00643	.99357		30
	45	.11754	.88246	8.5079	.11836	8.4490	1.0070	.00693	.99307		15
7	0	.12187	.87813	8.2055	.12278	8.1443	1.0075	.00745	.99255	83	0
	15	.12620	.87380	7.9240	.12722	7.8606	1.0081	.00800	.99200		45
	30	.13053	.86947	7.6613	.13165	7.5958	1.0086	.00856	.99144		30
	45	.13485	.86515	7.4156	.13609	7.3479	1.0092	.00913	.99086		15
8	0	.13917	.86083	7.1853	.14054	7.1154	1.0098	.00973	.99027	82	0
	15	.14349	.85651	6.9690	.14499	6.8969	1.0105	.01035	.98965		45
	30	.14781	.85219	6.7655	.14945	6.6912	1.0111	.01098	.98902		30
	45	.15212	.84788	6.5736	.15391	6.4971	1.0118	.01164	.98836		15
9	0	.15643	.84357	6.3924	.15838	6.3138	1.0125	.01231	.98769	81	0
	15	.16074	.83926	6.2211	.16286	6.1402	1.0132	.01300	.98700		45
	30	.16505	.83495	6.0589	.16734	5.9758	1.0139	.01371	.98629		30
	45	.16935	.83065	5.9049	.17183	5.8197	1.0147	.01444	.98556		15
10	0	.17365	.82635	5.7588	.17633	5.6713	1.0154	.01519	.98481	80	0
	15	.17794	.82206	5.6198	.18083	5.5301	1.0162	.01596	.98404		45
	30	.18224	.81776	5.4874	.18534	5.3955	1.0170	.01675	.98325		30
	45	.18652	.81348	5.3612	.18986	5.2672	1.0179	.01755	.98245		15
11	0	.19081	.80919	5.2408	.19438	5.1446	1.0187	.01837	.98163	79	0
	15	.19509	.80491	5.1258	.19891	5.0273	1.0196	.01921	.98079		45
	30	.19937	.80063	5.0158	.20345	4.9152	1.0205	.02008	.97992		30
	45	.20364	.79636	4.9106	.20800	4.8077	1.0214	.02095	.97905		15
12	0	.20791	.79209	4.8097	.21256	4.7046	1.0223	.02185	.97815	78	0
	15	.21218	.78782	4.7130	.21712	4.6057	1.0233	.02277	.97723		45
	30	.21644	.78356	4.6202	.22169	4.5107	1.0243	.02370	.97630		30
	45	.22070	.77930	4.5311	.22628	4.4194	1.0253	.02466	.97534		15
13	0	.22495	.77505	4.4454	.23087	4.3315	1.0263	.02563	.97437	77	0
	15	.22920	.77080	4.3630	.23547	4.2468	1.0273	.02662	.97338		45
	30	.23345	.76655	4.2837	.24008	4.1653	1.0284	.02763	.97237		30
	45	.23769	.76231	4.2072	.24470	4.0867	1.0295	.02866	.97134		15
14	0	24192	.75808	4.1336	.24933	4.0108	1.0306	.02970	.97030	76	0
	15	.24615	.75385	4.0625	.25397	3.9375	1.0317	.03077	.96923		45
	30	.25038	.74962	3.9939	.25862	3.8667	1.0329	.03185	.96815		30
	45	.25460	.74540	3.9277	.26328	3.7983	1.0341	.03295	.96705		15
15	0	.25882	.74118	3.8637	.26795	3.7320	1.0353	03407	.96593	75	0
		Co-sine.	Ver. Sin.	Secant.	Cotan	Tang.	Cosec.	Co-Vers.	Sine.	°	M.

From 75° to 90° read from bottom of table upwards.

°	M.	Sine.	Co-Vers.	Cosec.	Tang.	Cotan.	Secant.	Ver. Sin.	Cosine.		
15	0	.25882	.74118	3.8637	.26795	3.7320	1.0353	.03407	.96593	75	0
	15	.26303	.73697	3.8018	.27263	3.6680	1.0365	.03521	.96479		45
	30	.26724	.73276	3.7420	.27732	3.6059	1.0377	.03637	.96363		30
	45	.27144	.72856	3.6840	.28203	3.5457	1.0390	.03754	.96246	74	15
16	0	.27564	.72436	3.6280	.28674	3.4874	1.0403	.03874	.96126		0
	15	.27983	.72017	3.5736	.29147	3.4308	1.0416	.03995	.96005		45
	30	.28402	.71598	3.5209	.29621	3.3759	1.0429	.04118	.95882		30
	45	.28820	.71180	3.4699	.30096	3.3226	1.0443	.04243	.95757		15
17	0	.29237	.70763	3.4203	.30573	3.2709	1.0457	.04370	.95630	73	0
	15	.29654	.70346	3.3722	.31051	3.2205	1.0471	.04498	.95502		45
	30	.30070	.69929	3.3255	.31530	3.1716	1.0485	.04628	.95372		30
	45	.30486	.69514	3.2801	.32010	3.1240	1.0500	.04760	.95240		15
18	0	.30902	.69098	3.2361	.32492	3.0777	1.0515	.04894	.95106	72	0
	15	.31316	.68684	3.1932	.32975	3.0326	1.0530	.05030	.94970		45
	30	.31730	.68270	3.1515	.33459	2.9887	1.0545	.05168	.94832		30
	45	.32144	.67856	3.1110	.33945	2.9459	1.0560	.05307	.94693		15
19	0	.32557	.67443	3.0715	.34433	2.9042	1.0576	.05448	.94552	71	0
	15	.32969	.67031	3.0331	.34921	2.8636	1.0592	.05591	.94409		45
	30	.33381	.66619	2.9957	.35412	2.8239	1.0608	.05736	.94264		30
	45	.33792	.66208	2.9593	.35904	2.7852	1.0625	.05882	.94118		15
20	0	.34202	.65798	2.9238	.36397	2.7475	1.0642	.06031	.93969	70	0
	15	.34612	.65388	2.8892	.36892	2.7106	1.0659	.06181	.93819		45
	30	.35021	.64979	2.8554	.37388	2.6746	1.0676	.06333	.93667		30
	45	.35429	.64571	2.8225	.37887	2.6395	1.0694	.06486	.93514		15
21	0	.35837	.64163	2.7904	.38386	2.6051	1.0711	.06642	.93358	69	0
	15	.36244	.63756	2.7591	.38888	2.5715	1.0729	.06799	.93201		45
	30	.36650	.63350	2.7285	.39391	2.5386	1.0748	.06958	.93042		30
	45	.37056	.62944	2.6986	.39896	2.5065	1.0766	.07119	.92881		15
22	0	.37461	.62539	2.6695	.40403	2.4751	1.0785	.07282	.92718	68	0
	15	.37865	.62135	2.6410	.40911	2.4443	1.0804	.07446	.92554		45
	30	.38268	.61732	2.6131	.41421	2.4142	1.0824	.07612	.92388		30
	45	.38671	.61329	2.5859	.41933	2.3847	1.0844	.07780	.92220		15
23	0	.39073	.60927	2.5593	.42447	2.3559	1.0864	.07950	.92050	67	0
	15	.39474	.60526	2.5333	.42963	2.3276	1.0884	.08121	.91879		45
	30	.39875	.60125	2.5078	.43481	2.2998	1.0904	.08294	.91706		30
	45	.40275	.59725	2.4829	.44001	2.2727	1.0925	.08469	.91531		15
24	0	.40674	.59326	2.4586	.44523	2.2460	1.0946	.08645	.91355	66	0
	15	.41072	.58928	2.4348	.45047	2.2199	1.0968	.08824	.91176		45
	30	.41469	.58531	2.4114	.45573	2.1943	1.0989	.09004	.90996		30
	45	.41866	.58134	2.3886	.46101	2.1692	1.1011	.09186	.90814		15
25	0	.42262	.57738	2.3662	.46631	2.1445	1.1034	.09369	.90631	65	0
	15	.42657	.57343	2.3443	.47163	2.1203	1.1056	.09554	.90446		45
	30	.43051	.56949	2.3228	.47697	2.0965	1.1079	.09741	.90259		30
	45	.43445	.56555	2.3018	.48234	2.0732	1.1102	.09930	.90070		15
26	0	.43837	.56163	2.2812	.48773	2.0503	1.1126	.10121	.89879	64	0
	15	.44229	.55771	2.2610	.49314	2.0278	1.1150	.10313	.89687		45
	30	.44620	.55380	2.2412	.49858	2.0057	1.1174	.10507	.89493		30
	45	.45010	.54990	2.2217	.50404	1.9840	1.1198	.10702	.89298		15
27	0	.45399	.54601	2.2027	.50952	1.9626	1.1223	.10899	.89101	63	0
	15	.45787	.54213	2.1840	.51503	1.9416	1.1248	.11098	88902		45
	30	.46175	.53825	2.1657	.52057	1.9210	1.1274	.11299	.88701		30
	45	.46561	.53439	2.1477	.52612	1.9007	1.1300	.11501	.88499		15
28	0	.46947	.53053	2.1300	.53171	1.8807	1.1326	.11705	.88295	62	0
	15	.47332	.52668	2.1127	.53732	1.8611	1.1352	.11911	.88089		45
	30	.47716	.52284	2.0957	.54295	1.8418	1.1379	.12118	.87882		30
	45	.48099	.51901	2.0790	.54862	1.8228	1.1406	.12327	.87673		15
29	0	.48481	.51519	2.0627	.55431	1.8040	1.1433	.12538	.87462	61	0
	15	.48862	.51138	2.0466	.56003	1.7856	1.1461	.12750	.87250		45
	30	.49242	.50758	2.0308	.56577	1.7675	1.1490	.12964	.87036		30
	45	.49622	.50378	2.0152	.57155	1.7496	1.1518	.13180	.86820		15
30	0	.50000	.50000	2.0000	.57735	1.7320	1.1547	.13397	.86603	60	0
		Co-sine.	Ver. Sin.	Se-cant.	Cotan.	Tang.	Cosec.	Co-Vers.	Sine.	°	M.

From 60° to 75° read from bottom of table upwards.

°	M.	Sine.	Co-Vers.	Cosec.	Tang.	Cotan.	Secant.	Ver. Sin.	Cosine		
30	0	.50000	.50000	2.0000	.57735	1.7320	1.1547	.13397	.86603	60	0
	15	.50377	.49623	1.9850	.58318	1.7147	1.1576	.13616	.86384		45
	30	.50754	.49246	1.9703	.58904	1.6977	1.1606	.13837	.86163		30
	45	.51129	.48871	1.9558	.59494	1.6808	1.1636	.14059	.85941		15
31	0	.51504	.48496	1.9416	.60086	1.6643	1.1666	.14283	.85717	59	0
	15	.51877	.48123	1.9276	.60681	1.6479	1.1697	.14509	.85491		45
	30	.52250	.47750	1.9139	.61280	1.6319	1.1728	.14736	.85264		30
	45	.52621	.47379	1.9004	.61882	1.6160	1.1760	.14965	.85035		15
32	0	.52992	.47008	1.8871	.62487	1.6003	1.1792	.15195	.84805	58	0
	15	.53361	.46639	1.8740	.63095	1.5849	1.1824	.15427	.84573		45
	30	.53730	.46270	1.8612	.63707	1.5697	1.1857	.15661	.84339		30
	45	.54097	.45903	1.8485	.64322	1.5547	1.1890	.15896	.84104		15
33	0	.54464	.45536	1.8361	.64941	1.5399	1.1924	.16133	.83867	57	0
	15	.54829	.45171	1.8238	.65563	1.5253	1.1958	.16371	.83629		45
	30	.55194	.44806	1.8118	.66188	1.5108	1.1992	.16611	.83389		30
	45	.55557	.44443	1.7999	.66818	1.4966	1.2027	.16853	.83147		15
34	0	.55919	.44081	1.7883	.67451	1.4826	1.2062	.17096	.82904	56	0
	15	.56280	.43720	1.7768	.68087	1.4687	1.2098	.17341	.82659		45
	30	.56641	.43359	1.7655	.68728	1.4550	1.2134	.17587	.82413		30
	45	.57000	.43000	1.7544	.69372	1.4415	1.2171	.17835	.82165		15
35	0	.57358	.42642	1.7434	.70021	1.4281	1.2208	.18085	.81915	55	0
	15	.57715	.42285	1.7327	.70673	1.4150	1.2245	.18336	.81664		45
	30	.58070	.41930	1.7220	.71329	1.4019	1.2283	.18588	.81412		30
	45	.58425	.41575	1.7116	.71990	1.3891	1.2322	.18843	.81157		15
36	0	.58779	.41221	1.7013	.72654	1.3764	1.2361	.19098	.80902	54	0
	15	.59131	.40869	1.6912	.73323	1.3638	1.2400	.19356	.80644		45
	30	.59482	.40518	1.6812	.73996	1.3514	1.2440	.19614	.80386		30
	45	.59832	.40168	1.6713	.74673	1.3392	1.2480	.19875	.80125		15
37	0	.60181	.39819	1.6616	.75355	1.3270	1.2521	.20136	.79864	53	0
	15	.60529	.39471	1.6521	.76042	1.3151	1.2563	.20400	.79600		45
	30	.60876	.39124	1.6427	.76733	1.3032	1.2605	.20665	.79335		30
	45	.61222	.38778	1.6334	.77428	1.2915	1.2647	.20931	.79069		15
38	0	.61566	.38434	1.6243	.78129	1.2799	1.2690	.21199	.78801	52	0
	15	.61909	.38091	1.6153	.78834	1.2685	1.2734	.21468	.78532		45
	30	.62251	.37749	1.6064	.79543	1.2572	1.2778	.21739	.78261		30
	45	.62592	.37408	1.5976	.80258	1.2460	1.2822	.22012	.77988		15
39	0	.62932	.37068	1.5890	.80978	1.2349	1.2868	.22285	.77715	51	0
	15	.63271	.36729	1.5805	.81703	1.2239	1.2913	.22561	.77439		45
	30	.63608	.36392	1.5721	.82434	1.2131	1.2960	.22838	.77162		30
	45	.63944	.36056	1.5639	.83169	1.2024	1.3007	.23116	.76884		15
40	0	.64279	.35721	1.5557	.83910	1.1918	1.3054	.23396	.76604	50	0
	15	.64612	.35388	1.5477	.84656	1.1812	1.3102	.23677	.76323		45
	30	.64945	.35055	1.5398	.85408	1.1708	1.3151	.23959	.76041		30
	45	.65276	.34724	1.5320	.86165	1.1606	1.3200	.24244	.75756		15
41	0	.65606	.34394	1.5242	.86929	1.1504	1.3250	.24529	.75471	49	0
	15	.65935	.34065	1.5166	.87698	1.1403	1.3301	.24816	.75184		45
	30	.66262	.33738	1.5092	.88472	1.1303	1.3352	.25104	.74896		30
	45	.66588	.33412	1.5018	.89253	1.1204	1.3404	.25394	.74606		15
42	0	.66913	.33087	1.4945	.90040	1.1106	1.3456	.25686	.74314	48	0
	15	.67237	.32763	1.4873	.90834	1.1009	1.3509	.25978	.74022		45
	30	.67559	.32441	1.4802	.91633	1.0913	1.3563	.26272	.73728		30
	45	.67880	.32120	1.4732	.92439	1.0818	1.3618	.26568	.73432		15
43	0	.68200	.31800	1.4663	.93251	1.0724	1.3673	.26865	.73135	47	0
	15	.68518	.31482	1.4595	.94071	1.0630	1.3729	.27163	.72837		45
	30	.68835	.31165	1.4527	.94896	1.0538	1.3786	.27463	.72537		30
	45	.69151	.30849	1.4461	.95729	1.0446	1.3843	.27764	.72236		15
44	0	.69466	.30534	1.4396	.96569	1.0355	1.3902	.28066	.71934	46	0
	15	.69779	.30221	1.4331	.97416	1.0265	1.3961	.28370	.71630		45
	30	.70091	.29909	1.4267	.98270	1.0176	1.4020	.28675	.71325		30
	45	.70401	.29599	1.4204	.99131	1.0088	1.4081	.28981	.71019		15
45	0	.70711	.29289	1.4142	1.0000	1.0000	1.4142	.29289	.70711	45	0
		Cosine	Ver. Sin.	Secant.	Cotan.	Tang.	Cosec.	Co-Vers.	Sine.	°	M.

From 45° to 60° read from bottom of table upwards.

Table of Time in Different Units

Counting 9 hours per day and 300 days per year

	Second	Minute	Hour	Day	Week	Month
Year	9,720,000	162,000	2700	300	50	12
Month	810,000	13,500	225	25	$4\frac{1}{6}$	
Week	194,400	3,240	54	6		
Day	32,400	540	9			
Hour	3,600	60				
Minute	60					

Table of Time in Different Units

Counting 10 hours per day, and 300 days per year

	Second	Minute	Hour	Day	Week	Month
Year	10,800,000	180,000	3000	300	50	12
Month	900,000	15,000	250	25	$4\frac{1}{6}$	
Week	216,000	3,600	60	6		
Day	36,000	600	10			
Hour	3,600	60				
Minute	60					

MENSURATION

PLANE SURFACES

Quadrilateral. — A four-sided figure.

Parallelogram. — A quadrilateral with opposite sides parallel.

Varieties. — Square: four sides equal, all angles right angles. Rectangle: opposite sides equal, all angles right angles. Rhombus: four sides equal, opposite angles equal, angles not right angles. Rhomboid: opposite sides equal, opposite angles equal, angles not right angles.

Trapezium. — A quadrilateral with unequal sides.

Trapezoid. — A quadrilateral with only one pair of opposite sides parallel.

Diagonal of a square $= \sqrt{2 \times \text{side}^2} = 1.4142 \times \text{side}$.

Diag. of a rectangle $= \sqrt{\text{sum of squares of two adjacent sides}}$.

Area of any parallelogram = base × altitude.

Area of rhombus or rhomboid = product of two adjacent sides × sine of angle included between them.

Area of a trapezoid = product of half the sum of the two parallel sides by the perpendicular distance between them.

To find the area of any quadrilateral figure. — Divide the quadrilateral into two triangles; the sum of the areas of the triangles is the area.

Or, multiply half the product of the two diagonals by the sine of the angle at their intersection.

To find the area of a quadrilateral which may be inscribed in a circle. — From half the sum of the four sides subtract each side severally; multiply the four remainders together; the square root of the product is the area.

Triangle. — A three-sided plane figure.

Varieties. — Right-angled, having one right angle; obtuse-angled, having one obtuse angle; isosceles, having two equal angles and two equal sides; equilateral, having three equal sides and equal angles.

The sum of the three angles of every triangle = 180 degrees.

The sum of the two acute angles of a right-angled triangle = 90 degrees.

Hypothenuse of a right-angled triangle, the side opposite the right angle, $= \sqrt{\text{sum of the squares of the other two sides}}$. If

a and b are the two sides and c the hypothenuse, $c^2 = a^2 + b^2$; $a = \sqrt{c^2 - b^2} = \sqrt{(c + b)(c - b)}$.

If the two sides are equal, side = hyp ÷ 1.4142; or hyp × .7071.

To find the area of a triangle:

Rule 1. Multiply the base by half the altitude.

Rule 2. Multiply half the product of two sides by the sine of the included angle.

Rule 3. From half the sum of the three sides subtract each side severally; multiply together the half sum and the three remainders, and extract the square root of the product.

The area of an equilateral triangle is equal to one-fourth the square of one of its sides multiplied by the square root of 3, $= \frac{a^2\sqrt{3}}{4}$, a being the side; or $a^2 \times 0.433013$.

Area of a triangle given, to find base: Base = twice area ÷ perpendicular height.

Area of a triangle given, to find height: Height = twice area ÷ base.

Two sides and base given, to find perpendicular height (in a triangle in which both of the angles at the base are acute).

Rule. — As the base is to the sum of the sides, so is the difference of the sides to the difference of the divisions of the base made by drawing the perpendicular. Half this difference being added to or subtracted from half the base will give the two divisions thereof. As each side and its opposite division of the base constitutes a right-angled triangle, the perpendicular is ascertained by the rule: Perpendicular = $\sqrt{\text{hyp}^2 - \text{base}^2}$.

Areas of similar figures are to each other as the squares of their respective linear dimensions. If the area of an equilateral triangle of side = 1 is 0.433013 and its height 0.86603, what is the area of a similar triangle whose height = 1? $0.86603^2 : 1^2 :: 0.433013 : 0.57735$, Ans.

Polygon. — A plane figure having three or more sides. Regular or irregular, according as the sides or angles are equal or unequal. Polygons are named from the number of their sides and angles.

To find the area of an irregular polygon. — Draw diagonals dividing the polygon into triangles, and find the sum of the areas of these triangles.

Horse Power Transmitted by Cold-rolled Steel Shafting at Different Speeds as Prime Movers or Head Shafts Carrying Main Driving Pulley or Gear, well Supported by Bearings.

Formula H.P. = $d^3R \div 100$.

Revolutions per minute.						Revolutions per minute.					
Dia.	100	200	300	400	500	Dia.	100	200	300	400	500
$1\frac{1}{2}$	3.4	6.7	10.1	13.5	16.9	$2\frac{7}{8}$	24	48	72	95	119
$1\frac{9}{16}$	3.8	7.6	11.4	15.2	19.0	$2\frac{15}{16}$	25	51	76	101	127
$1\frac{5}{8}$	4.3	8.6	12.8	17.1	21.0	3	27	54	81	108	135
$1\frac{11}{16}$	4.8	9.6	14.4	19.2	24.0	$3\frac{1}{8}$	31	61	91	122	152
$1\frac{3}{4}$	5.4	10.7	16.1	21.0	27.0	$3\frac{3}{16}$	32	65	97	129	162
$1\frac{13}{16}$	5.9	11.9	17.8	24.0	30.0	$3\frac{1}{4}$	34	69	103	137	172
$1\frac{7}{8}$	6.6	13.1	19.7	26.0	33.0	$3\frac{3}{8}$	38	77	115	154	192
$1\frac{15}{16}$	7.3	14.5	22.0	29.0	36.0	$3\frac{7}{16}$	41	81	122	162	203
2	8.0	16.0	24.0	32.0	40.0	$3\frac{1}{2}$	43	86	128	171	214
$2\frac{1}{16}$	8.8	17.6	26.0	35.0	44.0	$3\frac{9}{16}$	45	90	136	180	226
$2\frac{1}{8}$	9.6	19.2	29.0	38.0	48.0	$3\frac{5}{8}$	48	95	143	190	238
$2\frac{3}{16}$	10.5	21.0	31.0	42.0	52.0	$3\frac{11}{16}$	50	100	150	200	251
$2\frac{1}{4}$	11.4	23.0	34.0	45.0	57.0	$3\frac{3}{4}$	55	105	158	211	264
$2\frac{5}{16}$	12.4	25.0	37.0	49.0	62.0	$3\frac{7}{8}$	58	116	174	233	291
$2\frac{3}{8}$	13.4	27.0	40.0	54.0	67.0	$3\frac{15}{16}$	61	122	183	244	305
$2\frac{7}{16}$	14.5	29.0	43.0	58.0	72.0	4	64	128	192	256	320
$2\frac{1}{2}$	15.6	31.0	47.0	62.0	78.0	$4\frac{3}{16}$	74	147	221	294	367
$2\frac{9}{16}$	16.8	34.0	50.0	67.0	84.0	$4\frac{1}{4}$	77	154	230	307	383
$2\frac{5}{8}$	18.1	36.0	54.0	72.0	90.0	$4\frac{7}{16}$	88	175	263	350	438
$2\frac{11}{16}$	19.4	39.0	58.0	77.0	97.0	4	91	182	273	365	456
$2\frac{3}{4}$	21.0	41.0	62.0	83.0	104.0	$4\frac{3}{4}$	107	214	322	429	537
$2\frac{13}{16}$	22.0	44.0	67.0	89.0	111.0	5	125	250	375	500	625

For H.P. transmitted by turned steel shafts, as prime movers, etc., multiply the figures by 0.8.

	Cold-rolled	Turned
For shafts, as second movers or line shafts, bearings 8 feet apart, multiply by	1.43	1.11
For simply transmitting power, short countershafts, etc., bearings not over 8 feet apart, multiply by	2	2.50

The horse power is directly proportional to the number of revolutions per minute.

Speed of Shafting. —

Machine shops .... 120 to 240
Wood-working.......................... 250 to 300
Cotton and woolen mills .... 300 to 400

Horse Power of a Leather Belt One Inch Wide. (Nagle.)

Formula: H.P. $= CVtw(S - 0.012\ V^2) \div 550$.
For $f = 0.40$, $a = 180$ degrees, $C = 0.715$, $w = 1$.

Laced Belts, $S = 275$.								Riveted Belts, $S = 400$.							
Velocity, ft. per sec.	Thickness in inches = t.							Velocity, ft. per sec.	Thickness in inches = t.						
	$\frac{1}{7}$	$\frac{1}{6}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{3}$		$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{3}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
10	0.51	0.59	0.63	0.73	0.84	1.05	1.18	15	1.69	1.94	2.42	2.58	2.91	3.39	3.87
15	0.75	0.88	1.00	1.16	1.32	1.66	1.77	20	2.24	2.57	3.21	3.42	3.85	4.49	5.13
20	1.00	1.17	1.32	1.54	1.75	2.19	2.34	25	2.79	3.19	3.98	4.25	4.78	5.57	6.37
25	1.23	1.43	1.61	1.88	2.16	2.69	2.86	30	3.31	3.79	4.74	5.05	5.67	6.62	7.58
30	1.47	1.72	1.93	2.25	2.58	3.22	3.44	35	3.82	4.37	5.46	5.83	6.56	7.65	8.75
35	1.69	1.97	2.22	2.59	2.96	3.70	3.94	40	4.33	4.95	6.19	6.60	7.42	8.66	9.90
40	1.90	2.22	2.49	2.90	3.32	4.15	4.44	45	4.85	5.49	6.86	7.32	8.43	9.70	10.98
45	2.09	2.45	2.75	3.21	3.67	4.58	4.89	50	5.26	6.01	7.51	8.02	9.02	10.52	12.03
50	2.27	2.65	2.98	3.48	3.98	4.97	5.30	55	5.68	6.50	8.12	8.66	9.74	11.36	13.00
55	2.44	2.84	3.19	3.72	4.26	5.32	5.69	60	6.09	6.96	8.70	9.28	10.43	12.17	13.91
60	2.58	3.01	3.38	3.95	4.51	5.64	6.02	65	6.45	7.37	9.22	9.83	11.06	12.90	14.75
65	2.71	3.16	3.55	4.14	4.74	5.92	6.32	70	6.78	7.75	9.69	10.33	11.62	13.56	15.50
70	2.81	3.27	3.68	4.29	4.91	6.14	6.54	75	7.09	8.11	10.13	10.84	12.16	14.18	16.21
75	2.89	3.37	3.79	4.42	5.05	6.31	6.73	80	7.36	8.41	10.51	11.21	12.61	14.71	16.81
80	2.94	3.43	3.86	4.50	5.15	6.44	6.86	85	7.58	8.66	10.82	11.55	13.00	15.16	17.32
85	2.97	3.47	3.90	4.55	5.20	6.50	6.93	90	7.74	8.85	11.06	11.80	13.27	15.48	17.69
90	2.97	3.47	3.90	4.55	5.20	6.50	6.93	100	7.96	9.10	11.37	12.13	13.65	15.92	18.20
The H.P. becomes a maximum at 87.41 ft. per sec. = 5245 ft. per min.								The H.P. becomes a maximum at 105.4 ft. per sec. = 6324 ft. per min.							

In the above table the angle of subtension, a is taken at 180 degrees.

Should it be............	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	200°
Multiply above values by.	.65	.70	.75	.79	.83	.87	.91	.94	.97	1	1.05

A. F. Nagle's Formula (*Trans. A. S. M. E.*, vol. ii, 1881, p. 91. Tables published in 1882).

$$\text{H.P.} = CVtw\left(\frac{S - 0.012\ V^2}{550}\right);$$

$C = 1 - 10^{-0.00758\,fa}$:
a = degrees of belt contact;
f = coefficient of friction;
w = width in inches;
t = thickness in inches;
v = velocity in feet per second;
S = stress upon belt per square inch.

MISCELLANEOUS NOTES ON BELTING.

Formulæ are useful for proportioning belts and pulleys, but they furnish no means of estimating how much power a particular belt may be transmitting at any given time, any more than the size of the engine is a measure of the load it is actually drawing, or the known strength of a horse is a measure of the load on the wagon. The only reliable means of determining the power actually transmitted is some form of dynamometer. (See *Trans. A. S. M. E.*, vol. xii, p. 707.)

If we increase the thickness, the power transmitted ought to increase in proportion; and for double belts we should have half the width required for a single belt under the same conditions. With large pulleys and moderate velocities of belt it is probable that this holds good. With small pulleys, however, when a double belt is used, there is not such perfect contact between the pulley-face and the belt, due to the rigidity of the latter, and more work is necessary to bend the belt-fibers than when a thinner and more pliable belt is used. The centrifugal force tending to throw the belt from the pulley also increases with the thickness, and for these reasons the width of a double belt required to transmit a given horse power when used with small pulleys is generally assumed not less than seven-tenths the width of a single belt to transmit the same power. (Flather on "Dynamometers and Measurement of Power.")

F. W. Taylor, however, finds that great pliability is objectionable, and favors thick belts even for small pulleys. The power consumed in bending the belt around the pulley he considers inappreciable. According to Rankine's formula for centrifugal tension, this tension is proportional to the sectional area of the belt, and hence it does not increase with increase of thickness when the width is decreased in the same proportion, the sectional area remaining constant.

Scott A. Smith (*Trans. A. S. M. E.*, x, 765) says: The best belts are made from all oak-tanned leather, and curried with the use of cod oil and tallow, all to be of superior quality. Such belts have continued in use thirty to forty years when used as simple driving-belts, driving a proper amount of power, and having had suitable care. The flesh side should not be run to the pulley-face, for the reason that the wear from contact with the pulley should come on the grain side, as that surface of the belt is much weaker in its tensile strength than the flesh side; also as the grain is hard it is more enduring for the wear of attrition; further, if the grain is actually worn off, then the belt may not suffer in its integrity from a ready tendency of the hard grain side to crack.

The most intimate contact of a belt with a pulley comes, first, in the smoothness of a pulley-face, including freedom from ridges and hollows left by turning-tools; second, in the smoothness of the surface and evenness in the texture or body of a belt; third, in having the crown of the driving and receiving pulleys exactly alike, — as nearly so as is practicable in a commercial sense; fourth, in having the crown of pulleys not over $\frac{1}{8}$ inch for a 24-inch face, that is to say, that the pulley is not to be over $\frac{1}{4}$ inch larger in diameter in its center; fifth, in having the crown other than two planes meeting at the center; sixth, the use of any material on or in a belt, in addition to those necessarily used in the currying process, to keep them pliable or increase their tractive quality, should wholly depend upon the exigencies arising in the use of belts; non-use is safer than over-use; seventh, with reference to the lacing of belts, it seems to be a good practice to cut the ends to a convex shape by using a former, so that there may be a nearly uniform stress on the lacing through the center as compared with the edges. For a belt 10 inches wide, the center of each end should recede $\frac{1}{10}$ inch.

Lacing of Belts. — In punching a belt for lacing, use an oval punch, the longer diameter of the punch being parallel with the sides of the belt. Punch two rows of holes in each end, placed zigzag. In a 3-inch belt there should be four holes in each end — two in each row. In a 6-inch belt, seven holes — four in the row nearest the end. A 10-in. belt should have nine holes. The edge of the holes should not come nearer than $\frac{3}{4}$ inch from the sides, nor $\frac{7}{8}$ inch from the ends of the belt. The second row should be at least $1\frac{3}{4}$ inches from the end. On wide belts these distances should be even a little greater.

Begin to lace in the center of the belt and take care to keep the ends exactly in line, and to lace both sides with equal tightness. The lacing should not be crossed on the side of the belt that runs next the pulley. In taking up belts, observe the same rules as in putting on new ones.

Setting a Belt on Quarter-twist. — A belt must run squarely on to the pulley. To connect with a belt two horizontal shafts at right angles with each other, say an engine-shaft near the floor with a line attached to the ceiling, will require a quarter-turn. First, ascertain the central point on the face of each pulley at the extremity of the horizontal diameter where the belt will leave the pulley, and then set that point on the driven pulley plumb over the corresponding point on the driver. This will cause the belt to run squarely on to each pulley, and it will leave at an angle greater or less, according to the size of the pulleys and their distance from each other.

In quarter-twist belts, in order that the belt may remain on the pulleys, the central plane on each pulley must pass through the point of delivery of the other pulley. This arrangement does not admit of reversed motion.

To find the Length of Belt required for two given Pulleys. — When the length cannot be measured directly by a tape-line the following approximate rule may be used: Add the diameter of the two pulleys together, divide the sum by 2, and multiply the quotient by $3\frac{1}{4}$, and add the product to twice the distance between the centers of the shafts.

ANALOGIES BETWEEN THE FLOW OF WATER AND ELECTRICITY

Water	Electricity
Head, difference of level, in feet. Difference of pressure, lbs. per sq. in.	Volts; electro-motive force; difference of potential; E. or E.M.F.
Resistance of pipes, apertures, etc., increases with length of pipe, with contractions, roughness, etc.; decreases with increase of sectional area.	Ohms, resistance, *R*. Increases directly as the length of the conductor or wire and inversely as its sectional area, $R \propto l \div s$. It varies with the nature of the conductor.
Rate of flow, as cubic ft. per second, gallons per min., etc., or volume divided by the time. In the mining regions sometimes expressed in "miners' inches."	Amperes: current; current strength; intensity of current; rate of flow; 1 ampere = 1 coulomb per second. Amperes $= \frac{\text{volts}}{\text{ohms}}$; $I = \frac{E}{R}$; $E = IR$.

Water	Electricity
Quantity, usually measured in cubic ft. or gallons, but is also equivalent to rate of flow × time, as cu. ft. per second for so many hours.	Coulomb, unit of quantity, Q, = rate of flow × time, as ampere-seconds. 1 ampere-hour = 3600 coulombs.
Work, or energy, measured in foot-pounds; product of weight of falling water into height of fall; in pumping, product of quantity in cubic feet into the pressure in lbs. per square foot against which the water is pumped.	Joule, volt-coulomb, W, the unit of work, = product of quantity by the electro-motive force = volt-ampere-second. 1 joule = 0.7373 foot-pound. If C (amperes) = rate of flow, and E (volts) = difference of pressure between two points in a circuit, energy expended = IEt, = I^2Rt.
Power, rate of work. Horse power = ft.-lbs. of work in 1 min. ÷ 33,000. In water flowing in pipes, rate of flow in cu. ft. per second × resistance to the flow in lbs. per sq. ft. ÷ 550.	Watt, unit of power, P, = volts × amperes, = current or rate of flow × difference of potential. 1 watt = 0.7373 foot-pound per sec. = 1/746 of a horse power.

TABLE OF ELECTRICAL HORSE-POWERS.

Formula: $\frac{\text{Volts} \times \text{Amperes}}{746} = \text{H.P.}$, or 1 volt ampere = .0013405 H.P.

Read amperes at top and volts at side or *vice versa.*

Amperes or Volts.	Volts or Amperes.												
	1	10	20	30	40	50	60	70	80	90	100	110	120
1	.00134	.0134	.0268	.0402	.0536	.0670	.0804	.0938	.1072	.1206	.1341	.1475	.1609
2	.00268	.0268	.0536	.0804	.1072	.1341	.1609	.1877	.2145	.2413	.2681	.2949	.3217
3	.00402	.0402	.0804	.1206	.1609	.2011	.2413	.2815	.3217	.3619	.4022	.4424	.4826
4	.00536	.0536	.1072	.1609	.2145	.2681	.3217	3753	.4290	4826	.5362	.5898	.6434
5	.00670	.0670	.1341	.2011	.2681	.3351	.4022	.4692	.5362	.6032	.6703	.7373	.8043
6	.00804	.0804	.1609	.2413	.3217	.4022	.4826	.5630	.6434	.7239	.8043	.8847	.9652
7	.00938	.0938	.1877	.2815	.3753	.4692	.5630	.6568	.7507	.8445	.9384	1.032	1.126
8	.01072	.1072	.2145	.3217	.4290	.5362	.6434	.7507	.8579	.9652	1.072	1.180	1.287
9	.01206	.1206	.2413	.3619	.4826	.6032	.7239	.8445	.9652	1.086	1.206	1.327	1.448
10	.01341	.1341	.2681	.4022	.5362	.6703	.8043	.9383	1.072	1.206	1.341	1.475	1.609
11	.01475	.1475	.2949	.4424	.5898	.7373	.8847	1.032	1.180	1.327	1.475	1.622	1.769
12	.01609	.1609	.3217	.4826	.6434	.8043	.9652	1.126	1.287	1.448	1.609	1.769	1.930
13	.01743	.1743	.3485	.5228	.6970	.8713	1.046	1.220	1.394	1.568	1.743	1.917	2.091
14	.01877	.1877	.3753	.5630	.7507	.9384	1.126	1.314	1.501	1.689	1.877	2.064	2.252
15	.02011	.2011	.4022	.6032	.8043	1.005	1.206	1.408	1.609	1.810	2.011	2.212	2.413
16	.02145	.2145	.4290	.6434	.8579	1.072	1.287	1.501	1.716	1.930	2.145	2.359	2.574
17	.02279	.2279	.4558	.6837	.9115	1.139	1.367	1.595	1.823	2.051	2.279	2.507	2.735
18	.02413	.2413	.4826	.7239	.9652	1.206	1.448	1.689	1.930	2.172	2.413	2.654	2.895
19	.02547	.2547	.5094	.7641	1.019	1.273	1.528	1.783	2.037	2.292	2.547	2.801	3.056
20	.02681	.2681	.5362	.8043	1.072	1.340	1.609	1.877	2.145	2.413	2.681	2.949	3.217
21	.02815	.2815	.5630	.8445	1.126	1.408	1.689	1.971	2.252	2.533	2.815	3.097	3.378
22	.02949	.2949	.5898	.8847	1.180	1.475	1.769	2.064	2.359	2.654	2.949	3.244	3.539
23	.03083	.3083	.6166	.9249	1.233	1.542	1.850	2.158	2.467	2.775	3.083	3.391	3.700
24	.03217	.3217	.6434	.9652	1.287	1.609	1.930	2.252	2.574	2.895	3.217	3.539	3.861
25	.03351	.3351	.6703	1.005	1.341	1.676	2.011	2.346	2.681	3.016	3.351	3.686	4.022
26	.03485	.3485	.6971	1.046	1.394	1.743	2.091	2.440	2.788	3.137	3.485	3.834	4.182
27	.03619	.3619	.7239	1.086	1.448	1.810	2.172	2.534	2.895	3.257	3.619	3.981	4.343
28	.03753	.3753	.7507	1.126	1.501	1.877	2.252	2.627	3.003	3.378	3.753	4.129	4.504
29	.03887	.3887	.7775	1.166	1.555	1.944	2.332	2.721	3.110	3.499	3.887	4.276	4.665
30	.04022	.4022	.8043	1.206	1.609	2.011	2.413	2.815	3.217	3.619	4.022	4.424	4.826
31	.04156	.4156	.8311	1.247	1.662	2.078	2.493	2.909	3.324	3.740	4.156	4.571	4.987
32	.04290	.4290	.8579	1.287	1.716	2.145	2.574	3.003	3.432	3.861	4.290	4.719	5.148
33	.04424	.4424	.8847	1.327	1.769	2.212	2.654	3.097	3.539	3.986	4.424	4.866	5.308
34	.04558	.4558	.9115	1.367	1.823	2.279	2.735	3.190	3.646	4.102	4.558	5.013	5.469
35	.04692	.4692	.9384	1.408	1.877	2.346	2.815	3.284	3.753	4.223	4.692	5.161	5.630
40	.05362	.5362	1.072	1.609	2.145	2.681	3.217	3.753	4 290	4.826	5.363	5.898	6.434
45	.06032	.6032	1.206	1.810	2.413	3.016	3.619	4.223	4.826	5.439	6.032	6.635	7.239
50	.06703	.6703	1.341	2.011	2.681	3.351	4.022	4.692	5.362	6.032	6.703	7.373	8.043
55	.07373	.7373	1.475	2.212	2.949	3.686	4.424	5.161	5.898	6.635	7.373	8.110	8.847
60	.08043	.8043	1.609	2.413	3.217	4.022	4.826	5.630	6.434	7.239	8.043	8.047	9.652
65	.08713	.8713	1.743	2.614	3.485	4.357	5.228	6.099	6.970	7.842	8.713	9.584	10.46
70	.09384	.9384	1.877	2.815	3.753	4.692	5.630	6.568	7.507	8.445	9.384	10.32	11.26
75	.10054	1.005	2.011	3.016	4.021	5.027	6.032	7.037	8.043	9.048	10.05	11.06	12.06
80	.10724	1.072	2.145	3.217	4.290	5.362	6.434	7.507	8.579	9.652	10.72	11.80	12.87
85	.11394	1.139	2.279	3.418	4.558	5.697	6.836	7.976	9.115	10.26	11.39	12.53	13.67
90	.12065	1.206	2.413	3.619	4.826	6.032	7.239	8.445	9.652	10.86	12.06	13.27	14.48
95	.12735	1.273	2.547	3.820	5.094	6.367	7.641	8.914	10.18	11.46	12.73	14.01	15.28
100	.13405	1.341	2.681	4.022	5.362	6.703	8.043	9.384	10.72	12.06	13.41	14.75	16.09
200	.26810	2.681	5.362	8.043	10.72	13.41	16.09	18.77	21.45	24.13	26.81	29.49	32.17
300	.40215	4.022	8.043	12.06	16.09	20.11	24.13	28.15	32.17	36.19	40.22	44.24	48.26
400	.53620	5.362	10.72	16.09	21.45	26.81	32.17	37.53	42.90	48.26	53.62	58.98	64.34
500	.67025	6.703	13.41	20.11	26.81	33.51	40.22	46.92	53.62	60.32	67.03	73.73	80.43
600	.80430	8.043	16.09	24.13	32.17	40.22	48.26	56.30	64.34	72.39	80.43	88.47	96.52
700	.93835	9.384	18.77	28.15	37.53	46.92	56.30	65.68	75.07	84.45	93.84	103.2	112.6
800	1.0724	10.72	21.45	32.17	42.90	53.62	64.34	75.07	85.79	96.52	107.2	118.0	128.7
900	1.2065	12.06	24.13	36.19	48.26	60.32	72.39	84.45	96.52	108.6	120.6	132.7	144.8
1.000	1.3405	13.41	26.81	40.22	53.62	67.03	80.43	93.84	107.2	120.6	134.1	147.5	160.9
2,000	2.6810	26.81	53.62	80.43	107.2	134.1	160.9	187.7	214.5	241.3	268.1	294.9	321.7
3,000	4.0215	40.22	80.43	120.6	160.9	201.1	241.3	281.5	321.7	361.9	402.2	442.4	482.6
4,000	5.3620	53.62	107.2	160.9	214.5	268.1	321.7	375.3	429.0	482.6	536.2	589.8	643.4
5,000	6.7025	67.03	134.1	201.1	268 1	335 1	402.2	469.2	536.2	603.2	670.3	737.3	804.3
6,000	8.0430	80.43	160.9	241.3	321.7	402.2	482.6	563.0	643.4	723.9	804.3	884.7	965.2
7,000	9.3835	93.84	187.7	281.5	375.3	469.2	563.0	656.8	750.7	844.5	938.4	1032	1126
8.000	10.724	107.2	214.5	321.7	429.0	536.2	643.4	750.7	857.9	965.2	1072	1180	1287
9,000	12.065	120.6	241.3	361.9	482.6	603.2	723.9	844.5	965.2	1086	1206	1327	1448
10,000	13.405	134.1	268.1	402.2	536.2	670.3	804.3	938.3	1072	1206	1341	1475	1609

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